THE ELECTRIC VEHICLE HAND-BOOK

CUSHING & SMITH

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The Electric Vehicle Hand-Book

BY

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PREFACE.

THE object of this hand-book is to set forth as clearly as possible the fundamental principles in the operation, care and maintenance of electric vehicles, their batteries, tires, motors, controllers and accessories.

The subject matter of each chapter has been compiled with the assistance of David F. Tobias, E.E., associate member American Institute of Electrical Engineers and with the collaboration of the leading experts in the various branches of the industry, with a view to assisting the owner and user in securing the highest efficiency possible in the operation of electric vehicles for every purpose.

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CHAPTER I.

ELECTRIC VEHICLE DEVELOPMENT.

By William P. Kennedy,
Consulting Transportation Engineer.

The electric vehicle is the most scientifically designed machine employed today in the transportation of city merchandise, and this is largely due to the fact that the data on which its design is based was fully developed in another, older and well established line of business (the electric railway) before the original project of producing electric vehicles was first taken up seriously in this country some fifteen years ago.

During the earlier period of its development it was natural to expect that considerable improvement would be necessary as the machine progressed from one stage of its development to another, but within a very short time a state of stability was attained which has not since been radically changed, although every advantage has been taken of the natural improvement anticipated in the development of batteries, tires and other equipment necessary to its use. This stability of the electric vehicle has been maintained for the past ten or twelve years and its practical utility is evidenced from the number of installations of these machines, which have been in operation continuously for this period. Their economy is proven by the fact that the owners of these original installations have since been the heaviest investors in the same kind of apparatus

and today almost all of the large installations throughout the country are made up of electric vehicles, the value of which in many cases amounts to a quarter of a million of dollars.

A contributing factor of importance in the situation has been the substantial character of the large industrial organizations which produce the vital parts of the equipment, such as the motors, controllers and batteries; and the continued fostering influence of these institutions is a guarantee to the investor in this type of motor vehicle that the value of his investment will rather increase than decrease with the continued extension of its use.

Another factor has been the variety of sizes in which these vital parts are available, whereby the equipment lends itself to extension or modification, thus insuring to the user that it is possible to select for the performance of his service an equipment that will meet his most exacting requirements, and furthermore, if, subsequent to its initial employment, the requirements of the service should change, adjustment can readily be made to suit the new conditions.

These characteristics of the essential equipment have been largely responsible for insuring the heavy investment by express companies and other such organizations where transportation plays an important part in the conduct of business, and it may safely be stated that no other type of motor vehicle has yet reached a similar degree of stability, nor such as to warrant anything like corresponding investment. This is principally due to the fact that

the other types have been under development for a much shorter period, but it is largely influenced by the mixed and unstable character of the equipment, and some considerable time must elapse before these other forms of machines will be on a par with the standardized design of the electric vehicle.

A particular advantage which exists at this time from the extended and continued use of electric vehicle equipments is that their economic superiority over other means of transportation and the cost of operation in all its details has been very well established in large installations, this information being one of the inducements offered to the majority of prospective users, who are largely, if not completely, influenced by the economies in their employment.

For passenger or pleasure service the electric vehicle has had a very extensive and continued use and they are employed in great number wherever their service as a convenience or pleasure has been enhanced by their reliability and ease of operation. As a general utility in the home, or for city service to the professional and business man, they have been used successfully in great number in nearly all of our large cities; their general use, as a matter of necessity, promoting the development of adequate means for their care and maintenance. The influence of these successfully operated pleasure vehicles has largely resulted in the adoption of the electric type for commercial employment, as the demonstration of their simplicity and low cost of

upkeep in the home has been taken advantage of by keen business men for their more serious problems of business delivery service.

With such evidence demonstrating constant well ordered development, an unlimited scope for application in city and local suburban service, extensive employment by the most conservative types of business organizations and by the most refined and cautious of our social circles; why, it may be asked, has not the electric vehicle attained an almost universal employment within its legitimate province of domestic utility and city merchandise transportation?

This has been a dominant question throughout the whole period of electric vehicle history and has been somewhat of a paradox in view of the persistent and qualified energy expended by its patient and enthusiastic advocates on the one hand and the constantly increasing tendency of our communities to employ electric utilities for domestic conveniences or commercial expediency on the other.

Fundamentally, the anticipated general adoption of the electric machine, within its well recognized economic sphere, is as certain of development as any of the other great industrial devices employed to perform work by means of electric current have been; but the project of its exploitation has been surrounded by difficulties which have no parallel in any other of our electrical developments. Fortunately, these difficulties are external to the machine itself and are confined solely to a bias of human mind, under extraordinary influence of the

collateral development of the gasolene machine, coupled with the usual impedimental reluctance to change from accustomed habit, which is the common obstacle to all human progress.

The machine being fundamentally based on principles of design proven safe in other commercial applications and capable of adaption to such variety of service as may be expected in its field of utility, the question appearing above may be regarded as a transitory one, which time in the natural course of events will answer affirmatively by demonstration of the machine's supremacy. It may be interesting, however, to analyze a few of the causes obstructing the progress naturally to be expected, with the purpose in view of emphasizing the passing character of these obstacles.

Coincident with the incipiency of the automobile industry in this country, about fifteen years ago, the electric vehicle appeared with all the promise which has ever since made the prospect of its development a fascinating, though somewhat illusive pursuit. Enhanced by the influence of the recent, or contemporary, successful evolution of the electric street railway industry, its commercial application was readily appreciated, although large scale manufacture was first undertaken in the direction of the passenger, or pleasure, vehicle in the belief that it was a temporary means leading to the more serious problem of commercial machine manufacture.

Early experience proved that there was a ready market for the pleasure car and in catering to this

demand the underlying project was deferred for a time, probably with recognition of the more difficult task involved in commercial machine application and service. However, within a few years the latent possibilities of the business field began to assert themselves and a variety of the lighter types of electric motor vehicles were developed and rendered service so much superior to the horse that the potentialities of the device in various forms began to be perceived by the promoter and before long this infant industry was subjected to an abnormal and untimely expansion, from the disastrous results of which it required many years to recover. This promotion took the form of public service or taxi-cab exploitation in all the principal cities of the Union, before a sufficient period has elapsed to permit of a natural development of the apparatus or any rational solution of the intricate problems involved in such an undertaking. As might be suspected the motive of the projectors of this scheme was not the fostering of legitimate progress in the art of manufacturing or applying the electric machine, but rather the flotation of securities, the manipulation of which afforded the means of acquiring financial gain inconsistent with the earning power of the machine in its rational application.

Needless to point out the "failures" resulting under such operation were widely advertised and of course charged to the machine instead of to the manipulators.

This was the first real setback which the industry received and it required some years to recover from.

its effects. In the meantime all of the underlying principles of design and development had been worked out and the capacities and limitations of a variety of equipments well established in rigid and severe service.

The electric pleasure vehicle progressed with a natural and steady growth, hundreds going into use yearly and a widespread knowledge being gained in their care and maintenance. The commercial vehicle was unfortunately destined for another very serious check to the normal extension of its use, which it again received from the hands of unscrupulous promoters. At this time they appeared in the form of selling agents, who without any financial interest in, or obligation to protect, the source of production, made contracts to sell factory outputs and being chiefly interested in the margin of profit at which the machines could be sold proceeded to unload them on the unsuspecting purchasers, by representation as to their life and performance which could not be met by the equipment disposed of. This campaign had naturally a limited life and although there was some advantage gained for the industry by placing a large number of machines in service, the reaction from such malpractice was a severe blow from which it has only recently recovered.

The loss of progress engendered by these obstacles has afforded the gasolene machine some considerable advantage in overtaking the electric in its bid for patronage among prospective merchant users, but the interval ensuing since the beginning

of the gasolene commercial car industry has not been sufficient to develop or perfect the elemental units of its power plant and transmission equipment to be on a par with the degree of perfection existing at present in the electric. Hence, the discerning purchaser is not yet inclined to invest to the same extent in the gasolene, as he does, with assurance, in electric equipment.

A diagnosis of the causes contributing at present to hinder, or postpone, the maturity of electric vehicle application would indicate that all of them are of temporary character and the general condition only requires a reasonable amount of patience with increased vigor and energy in the general direction which its ardent advocates have been pursuing.

The principal disadvantage of the moment is that the preliminary, or missionary, work of converting the more progressive part of the merchant community to use motor vehicles for business purposes having been accomplished, the pendulum has swung in the extreme opposite direction. Fired by the actual example of what they can perform with their touring cars, they are crazed with the desire for speed and distance performance in business, which is preposterous when compared with what they have been accustomed to with animal service. However, nothing else will do for the moment and they must have high powered high speed gasolene machines to do the work. Such enthusiasts seldom take sober advice, their experience is bought and paid for by themselves and, while it may require

some interval, a time is likely to come when they will have been taught that cost goes up at about the same rate as the square of the speed.

The greatest offenders in this application of motor vehicles are those minor executives, in otherwise well conducted and conservative organizations, to whom, for one reason or another not connected with proficiency in transportation problems, authority has been delegated to select and purchase machine equipment. In such cases the cost of operation or the use of reason is usually subordinated to securing spectacular performance, which is expected to crown them with glory in the eyes of their superiors.

Time is not far distant when reconsideration will bring back the swing of the pendulum to normal, and already it is beginning to be recognized that about ninety per cent. of the gasolene motor trucks now in use are doing work well within the range of ability of the electric and with mileages which are seldom over thirty-five miles per day, due to the limited period available for actual running time.

Much of the inconsistent prejudice which has existed against electrical equipment is obviously disappearing as is evidenced by the mad rush on at present among manufacturers to perform all the functions in gasolene machines by means of electrical equipment. Electric lighting, starting, signalling and in some instances change-gear operation and complete transmission are now the vogue for pleasure cars. When this practice extends to

the commercial type it will not be difficult to convince the prospective purchaser, that the mysteries of electric equipment having disappeared, the inert storage battery and the rotary motor are an economic ideal in contrast with an engine having a multiplicity of high speed reciprocating parts, in conjunction with a collection of highly specialized electrical auxiliary apparatus.

As a matter of fact we may justly regard the advance of the commercial gasolene machine as the greatest co-operative activity which the half dozen courageous electric vehicle manufacturers are sure of as a positive and direct agent for their advancement. There have been many attempts at co-operative assistance in propagating the use of electric vehicles, some of which have been highly potential but unfortunately more latent than active. Hence, even though in the temporary disguise of a competitor, the most valuable stimulant is that influence which precipitates the abandonment of animal use for machine service; the real impediment to electric vehicle introduction, as demonstrated over the entire period of its history, being the mental attitude assumed towards it, rather than any problem connected with its electrical or mechanical equipment.

CHAPTER II.

LEAD STORAGE BATTERIES, DESCRIPTION.

The storage battery is the part of the electric vehicle which holds the energy necessary for propulsion. It is the heart of the vehicle and so should receive proper care and attention. It consists of a number of cells or units grouped in trays according to the size and character of the vehicle. Each "cell" consists of a jar containing a number of plates properly connected, spaced with separators and immersed in a solution or electrolyte.

There are two classes of storage batteries enjoying commercial representation. These are, the lead-sulphuric-acid and nickel-iron-alkaline cells. A description of each of these important divisions will be given in order that the instructions covering their care and operation may be more easily and fully understood.

LEAD BATTERIES.

Historically the *lead battery* is the oldest form of storage cell used to any extent for vehicle service. The name *lead-acid battery* is given because the plates of the cells are made of lead and the solution is sulphuric-acid.

The plates of a lead battery are of two kinds, *positive* (+) and *negative* (—), Figs. 1 and 2, arranged alternately in the cell, there usually being an excess of one negative plate so that all surfaces of the positive plates may be active. The plates of

batteries used in vehicle service are of two general sizes, 4¾" x 8⅝" or 5¾" x 8⅝" and from ⅛"

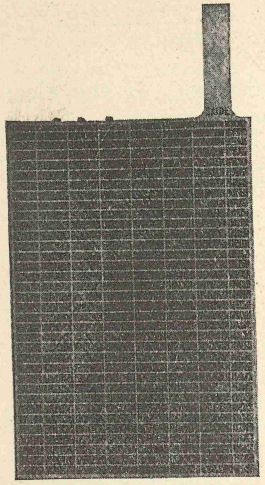


Fig. 1—Positive Plate.

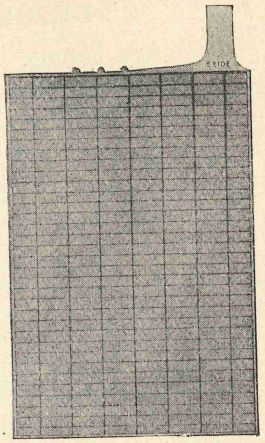


Fig. 2—Negative Plate.

to ⅜" in thickness, depending upon the requirements as explained later. By means of lead connecting *straps* (Fig. 3) all the positive plates in each cell are joined into what is known as a *positive group;* all the negative plates similarly into a *nega-*

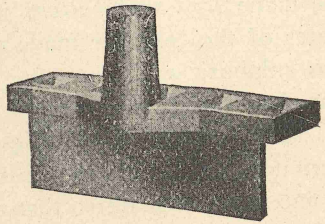


Fig. 3A—Pillar Strap.

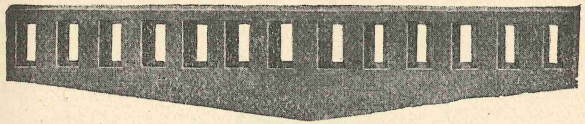


Fig. 3B—Straight Strap.

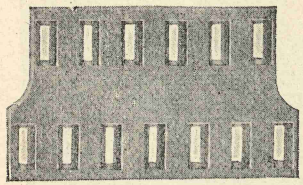


Fig. 3C—Plate Strap.

tive group. These two groups, with the *separators* (Fig. 4) for keeping the positive plates from mak-

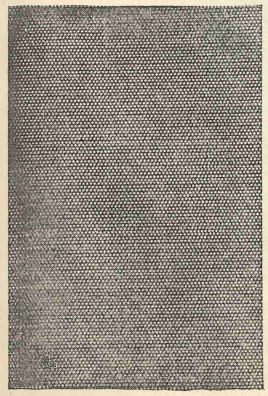
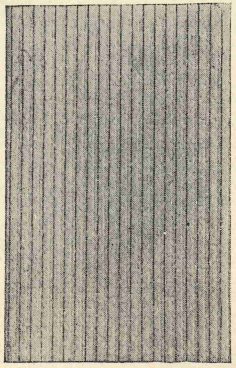


Fig. 4—Rubber Separator.



Wood Separator.

ing contact with the negative plates, form an *element* (Fig. 5). A hard rubber *jar* contains this element,

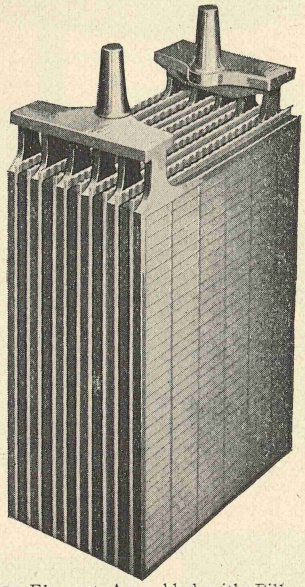


Fig. 5—Element Assembled with Pillar Straps.

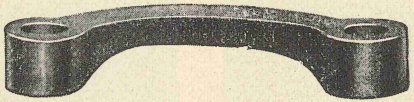


Fig. 7—Pillar Strap Connector.

immersed in a solution of sulphuric acid called *electrolyte,* the complete unit being called a *cell* (Fig. 6). A hard rubber cover is usually sealed over the top of the cell to reduce evaporation and

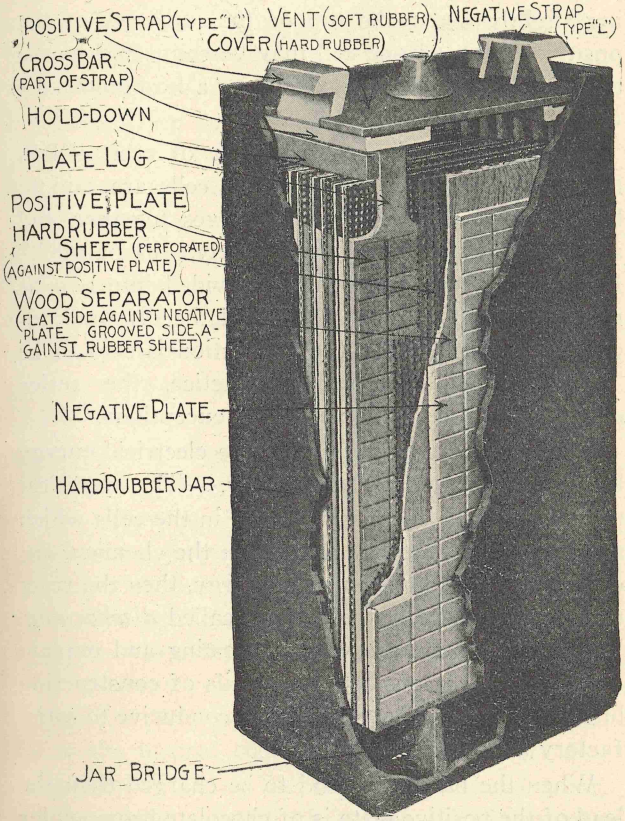


Fig. 6—Cell, Showing Parts.

spraying. The sealing compound is easily applied or removed when slightly heated.

The connecting straps, besides connecting the plates of a group, have a *pole* or *terminal,* extending slightly above the top of the jar, so that the positive group of one cell may be connected to the negative group of the next cell by a lead *connector* (Fig. 7).

By connecting the *negative pole* of each cell to the *positive pole* of the next, the cells are said to be connected in *series;* all Positives together and all Negatives together, respectively, "in parallel." If the total number of cells is divided into two or more parts, of cells in series, and the divisions together in parallel then the connection is said to be "series-parallel." In vehicle practice, the series grouping is used with very few exceptions.

A storage battery does not store electrical energy but holds the energy chemically. The electrical power produces chemical changes in the cells which are known as *charging,* and when the chemical energy is converted to electrical energy, then the reactions taking place in the cell are called *discharging.* These phenomena are very interesting and explain not only the reasons for the details of construction but the method of operation most conducive to satisfactory and efficient results.

When the battery is said to be charged then the lead of the positive plate is of chocolate brown color and is called lead peroxide while the negative plate is gray colored and consists of metallic lead in a form called spongy lead. This action is caused by

the passage of current from the positive to the negative plate through the electrolyte. When the current is reversed by connecting the positive and negative poles through external resistance then the reaction known as discharge takes place, and the lead peroxide of the positive plate is converted to lead sulphate of lighter brown color and the negative plate from spongy lead to lead sulphate, light slate in color. Pure lead sulphate is white, but as it is mixed with the lead peroxide and sponge lead, in the plates according to the extent to which the reactions of charge or discharge have taken place, the color of the plate will depend on how far the plate has been charged or discharged. In other words, the more the discharge the lighter the color and the more complete the charge the darker. These colors, however, are relative and give definite indications only to those experienced.

The action described above takes place over the surface of the plates but extends only very slightly within when sheets of lead are used as the plates. This layer or film of chemically active lead is therefore called *active material.* During that part of the cycle when the cell is discharged, the active material consists to a great extent of lead sulphate, so that the plate is said to be sulphated. *Sulphation* is the normal condition of the plates on discharge and is caused by the sulphuric acid going into the plates. Inasmuch as the specific gravity of the electrolyte decreases in proportion to the increase of sulphation in the plates, low specific gravity is the indication of the extent of sulphation or

of the extent of discharge. This indication is very important since in charging when the sulphate is removed from the plates, returned to the electrolyte, the battery is charged and the rise in specific gravity shows its progress. When the specific gravity has remained stationary for some time then no more sulphate is being transferred to the solution, the useful chemical action is completed, and the charging should be discontinued.

Lead sulphate is hard so that a discharged negative feels harder than a charged one, because the surface is covered with it. If the current is not supplied long enough to reduce all of the sulphate then it hardens and requires still more current to reduce it on the following charge. This is *undercharging*. If the plates be allowed to stand long in a discharged condition, then the hardening of the sulphate requires an excessive amount of charging beyond that normally needed, or *overcharging*, to bring the plates back to healthy condition. It is necessary to do this as the pores of the plate would otherwise be clogged, and less surface be useful.

When the current has charged the plates sufficiently for the greater part of lead sulphate to be decomposed then the further passage of current is spent not in useful chemical action (as that is complete), but in breaking up the electrolyte into hydrogen and oxygen gas. When thus liberated the gaseous particles are said to be nascent, and are particularly violent in their action. They are formed during the entire charge and act on the sulphate. The action of the hydrogen reduces the sulphate

leaving spongy lead on the negative plate and the oxygen oxidizes the sulphate of the positive plate to lead peroxide. These actions being completed, the same amount of current continues to produce the same amount of gaseous particles, which, finding no sulphate to reduce or oxidize, force their way through the active material and out of the solution as gas. The more violent and rapid the gassing, the greater is the tendency for small particles of active material to be forced off of the plate surface to fall to the bottom of the cell as *sediment*. As the coherence of the positive active material is considerably less than that of the negative, excessive gassing deteriorates the positive plate most rapidly. From this it will be seen that the gassing should be kept a minimum and is accomplished by reducing the current gradually until the plates are fully charged. The values of current used in charging are called *charging rates* and those in discharge, *discharge rates*. They will be explained in detail on page 26.

The discussion in the preceding lines assumed only two lead sheets as plates to begin with. In vehicle service, however, a minimum of weight with a maximum of capacity during life is a very important feature, so that instead of making use of only a thin layer of active material on a thick sheet of lead which is inherently heavy, the active material is formed chemically and firmly pressed into a light but strong network or frame of lead alloy. This frame or *grid* (Fig. 8), is characterized by the necessity for strength to hold the greatest amount

of active material firmly in the least space and to withstand the stresses of expansion and contraction as well as to present good conductivity to the passage of the electric current. This type of plate, invented by Faure, is the *Pasted plate,* and is practically standard for vehicle use. Both positive and negative plates are made in this manner.

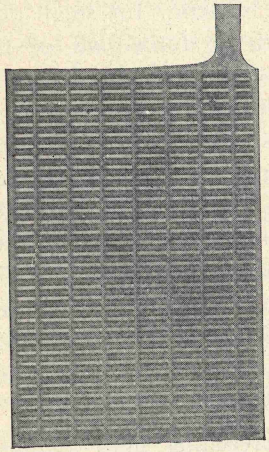


Fig. 8—**Positive Grid.**

Negative Grid.

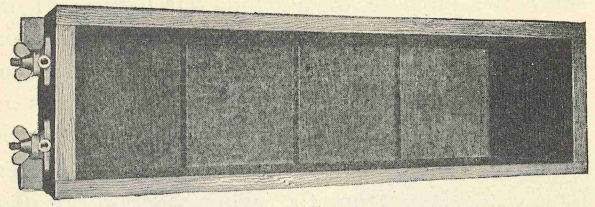
Another form of positive plate is one having slotted hard rubber tubes as the containers of the active material. These tubes have a cylindrical lead alloy core fastened to the grid at top and bottom and are surrounded by lead peroxide held by the casing in order that the shedding of active material may be reduced and the effective surface increased.

The *separators* which correctly space the plates

are of two kinds, thin sheets of perforated hard rubber and thin ribbed wood, chemically treated to remove injurious impurities. One side of this wood separator is flat, pressing against the negative plate while the other side presses the rubber sheet against the surface of the positive plate. The separators serve the purpose of allowing circulation of the electrolyte and escape of gas, while preventing contact of the plates which would cause a short circuit in the cells. Through vibration, the separators are liable to work loose and float up from the bottom of the plates, exposing them to contact. To prevent this, extensions from the under side of the plate straps, or hard rubber blocks are made use of in holding the separators in position (Fig. 6).

The containing jars are composed of hard rubber compound, of dimensions that will snugly contain the assembled elements, leaving a space of from 1″ to 3″ under the bottom of the plates to collect sediment and about 1½″ above the tops of the plates to allow sufficient height of electrolyte without slopping over. The tops of the jars are fitted with covers, having openings for adding pure water (to replace evaporation) and are provided with vent plugs to allow the escape of gas. These covers are generally sealed on with a compound to avoid sloppage, reduce evaporation and prevent introduction of foreign material. Two supporting ribs or *bridges* cast integral with the bottom of the jar, are provided to support the element and provide space for the collection of sediment without allowing it to come in contact with the plates.

A *tray* (Figs. 9 and 10) is used to hold a number of cells rigidly in the vehicle and protect the containing jars from damage as well as admit of convenient handling in assembly or removal from the battery compartment. These trays are built



Tray, Showing Slatted Bottom.

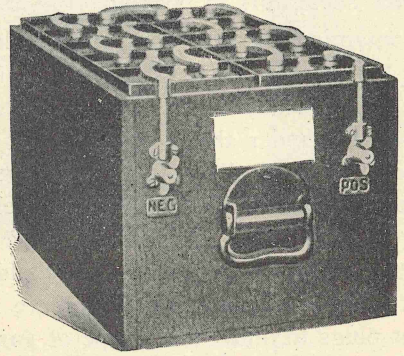


Fig. 9—Tray, Showing Cell Assembly.

of hard wood treated with acid-resisting paint. Handles for handling and connectors for making secure connections to the wiring of the vehicle are placed on the outside of the tray ends. A *name*

plate is usually attached at a conspicuous point for ready reference.

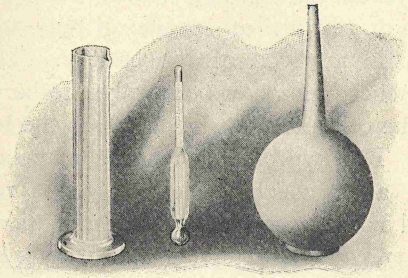


Fig. 10—Acid Testing Set.

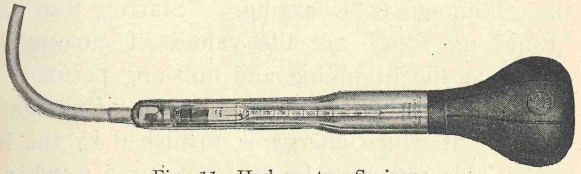


Fig. 11—Hydrometer Syringe.

The process of attaching the plates to the connecting straps to form the positive and negative groups, and the connectors to the poles, is known as *lead burning* and consists in the application of a flame of sufficient heat to weld or melt the lead parts into one. This is similar to soldering, except that in this case no flux is used and the flame is applied to the parts directly. For temporary repairs soldering may be applied, but not otherwise. This process is described in detail on page 100.

The specific gravity or relative density of a solution is determined by the use of an acid testing set (Fig. 10) or a hydrometer syringe (Fig. 11). The hydrometer syringe is most convenient as it permits a reading of specific gravity to be taken quickly in any cell of the battery. The syringe with rubber bulb allows electrolyte to be withdrawn from the cell into the tube in which the hydrometer floats. The hydrometer reading may be thus observed, after which the electrolyte is returned to the cell without spilling or contamination.

CHARGE AND DISCHARGE RATES.

The "Charging Rate" is the current measured in amperes, used to effect the chemical changes in the cell known as "Charging." "Starting Rate" and "Finishing Rate" are the values of current employed at the beginning and finishing periods.

The "Discharge Rate" is the value of current in amperes at which energy is furnished by the battery. This rate may be constant for a number of hours as on a laboratory test or may vary considerably as when furnishing current to the motor. The length of time in hours during which the battery will deliver its catalogue discharge rate before reaching 1.7 volts per cell, multiplied by the discharge rate in amperes, gives the "Discharge Capacity" of the battery in ampere-hours.

In charging, since the storage battery is not 100% efficient in operation, it is necessary to add from 5 to 15% more ampere-hours of charge than are recovered in ampere-hours of discharge. As it is not possible to charge continuously at the same

rate as that at which the battery may be discharged, several hours more are needed to completely charge than are required to discharge at the catalogue discharge rate. The catalogue charge and discharge rate established by the manufacturers are neither maximum nor minimum values for the cells in question but average or moderate figures which experience and test have shown to be acceptable for all ordinary variations of vehicle service.

TABLE I.

"EXIDE" ELECTRIC STORAGE BATTERY COMPANY

Type of Cell.	No. of Plates in Cell.	Ampere Hour Capacity.	Normal Discharge Rate.	Charging Rates in Amperes. Start.	Finish.	Initial Charge. Rate in Amperes.	Length of Charge.	Size of Plates.
"Exide" P V	5	48	12	12	5	25% of Normal Discharge Rate	Until Voltage and Sp. Gr. Remain a Maximum for 10 Hrs.	4 13/16" x 8⅝"
	7	72	18	17	6			
	9	96	24	21	8			
	11	120	30	25	10			
"Exide" M V	7	84	21	20	7			5¾" x 8⅝"
	9	112	28	25	9			
	11	140	35	29	12			
	13	168	42	35	14			
	15	196	49	40	16			
	17	224	56	46	18			
	19	252	63	51	20			
	21	280	70	56	22			
"Hycap-Exide" P V	9	92.5	18.5	18	7			4 13/16" x 8⅝"
	11	115.0	23.0	22	8			
	13	137.5	27.5	25	10			
"Hycap-Exide" M V	9	110.0	22.0	21	8			5¾" x 8⅝"
	11	137.5	27.5	25	10			
	14	165.0	33.0	29	12			
	15	192.5	38.5	34	13			
	17	220.0	44.0	39	15			
	19	247.5	49.5	43	17			
	21	275.0	55.0	47	19			
	23	302.5	60.5	52	20			
	25	330.0	66.0	56	22			

ELECTRIC STORAGE BATTERY COMPANY (CONTINUED)

"Thin-Exide"	11	127.5	21.25	21	8			8¾" x ⅝"
	13	153.0	25.5	25	9			
	15	168.50	29.75	28	11			
	17	204.0	34.0	32	12			
	19	229.50	38.25	35	14			
	21	255.0	42.5	39	15			
	23	280.50	46.75	42	17			
	25	306.00	51.00	46	18			
	27	331.50	55.25	49	19			
	29	357.00	59.50	52	21			
	31	382.50	63.75	56	22			
"Iron-Clad Exide" P V	5	54	12	12	5			4 15/16" x 8⅝"
	7	81	18	17	6			
	9	108	24	21	8			
	11	135	30	25	10			
"Iron-Clad Exide" M V	7	94.5	21	20	7			5 ¾" x 8⅝"
	9	126.0	28	25	9			
	11	157.5	35	29	12			
	13	189	42	35	14			
	15	220.5	49	40	16			
	17	252.0	56	46	18			
	19	283.5	63	51	20			
	21	315.0	70	56	22			

NOTE.—Initial charge applies only when plates are received undeveloped.

TABLE II.

GOULD STORAGE BATTERY COMPANY

Type of Cell.	No. of Plates in Cell.	Ampere Hour Capacity.	Normal Discharge Rate.	Charging Rates in Amperes. Start.	Finish.	Initial Charge. Rate in Amperes.	Length of Charge.	Size of Plates.
RP	7	84	21	16	6	10	Until Voltage and Sp. Gr. Remain a Maximum for 10 Hrs.	5 5/8" x 8 5/8"
	9	112	28	22	8	13		
	11	140	35	27	10	16.5		
	13	168	42	33	12	20.0		
	15	196	49	38	14	23.0		
	17	224	56	44	16	26.5		
	19	252	63	49	18	30.0		
	21	280	70	55	20	33.0		
MC	9	112	24	20	8	13.0		5 5/8" x 8 5/8"
	11	140	30	25	10	16.5		
	13	168	36	30	12	20.0		
	15	196	42	35	14	23.0		
	17	224	48	40	16	26.5		
	19	252	54	45	18	30.0		
	21	280	60	50	20	33.0		
	23	308	66	55	22	36.5		
	25	336	72	60	24	40.0		

GOULD STORAGE BATTERY COMPANY (CONTINUED)

TH	9	110	20	16	8	12	5 5/8" x 8 5/8"
	11	138	25	20	10	15	
	13	165	30	24	12	18	
	15	193	35	28	14	21	
	17	220	40	32	16	24	
	19	248	45	36	18	27	
	21	275	50	40	20	30	
	23	303	55	44	22	33	
	25	330	60	48	24	36	
	27	358	65	52	26	39	
	29	385	70	56	28	42	
NH	7	68	13.5	10.5	5.5	8	4 13/16" x 8 5/8"
	9	90	18.0	14.0	7.0	11	
	11	113	22.5	17.5	9.0	13.5	
	13	135	27.0	21.0	10.5	16.0	
	15	158	31.5	24.5	12.5	19.0	
NR	5	48	12	7.0	4.0	5	4 13/16" x 8 5/8"
	7	72	18	10.5	5.5	8	
	9	96	24	14.0	7.0	13.5	
	11	120	30	17.5	9.0	16.0	
	13		36	21.0	10.5	19.0	
	15		42	24.5	12.5	22.0	

NOTE.—Initial charge applies only when plates are received undeveloped.

TABLE III.

PHILADELPHIA STORAGE BATTERY COMPANY

Type of Cell.	No. of Plates in Cell.	Ampere Hour Capacity.	Normal Discharge Rate.	Charging Rates in Amperes. Start.	Finish.	Initial Charge. Rate in Amperes.	Length of Charge.	Size of Plates.
W	7	84	21	21	5	30% of Normal Discharge Rate	Until Voltage and Sp. Gr. Remain a Maximum for 10 Hrs.	5¾" x 8⅝"
	9	112	28	28	7			
	11	140	35	35	9			
	13	168	42	42	11			
	15	196	49	49	13			
	17	224	56	56	15			
	19	252	63	63	17			
	21	280	70	70	19			
WM	9	112	22.4	23	5			5¾" x 8⅝"
	11	140	28.0	28	7			
	13	168	33.6	34	9			
	15	196	39.2	40	10			
	17	224	44.8	45	12			
	19	252	50.4	51	14			
	21	280	56.0	56	15			
	23	308	61.6	62	17			
	25	336	67.2	68	19			
WT	9	108	18	18	4			5¾" x 8⅝"
	11	135	22.5	24	5			
	13	162	27.0	27	7			
	15	189	31.5	32	8			
	17	216	36.0	36	10			
	19	242	40.5	40	11			
	21	270	45.0	45	12			
	23	297	49.5	50	14			
	25	324	54.0	55	15			
WTX	9	102	17.0	17	4			5¾" x 8⅝"
	11	127.5	21.25	22	5			
	13	153.0	25.50	25	6			
	15	168.5	29.75	30	8			
	17	204.0	34.00	34	9			
	19	229.5	38.25	38	10			
	21	255.0	42.50	43	12			
	23	280.5	46.75	47	13			
	25	306.0	51.00	51	14			
	27	331.5	55.25	55	16			
	29	357.0	59.50	60	17			
	31	382.5	63.75	64	18			
	33	408.0	68.00	68	20			
C	5	48	12	12	4			4 13/16" x 8⅝"
	7	72	18	18	5			
	9	92	24	24	6			
	11	120	30	30	7			
CM	7	72	14.4	15	4			4 13/16" x 8⅝"
	9	96	19.2	19	5			
	11	120	24.0	24	6			
	13	144	28.8	29	7			
CT	7	67.5	11.25	15	4			4 13/16" x 8⅝"
	9	90.0	15.0	19	5			
	11	112.5	18.75	23	6			
	13	133.5	22.25	27	7			
	15	157.5	26.25	31	8			
R	7	60	15	12	3			4 15/16" x 7⅝"
	9	80	20	15	4			
	11	100	25	20	5			
	13	120	30	25	6			
	15	140	35	30	7			

NOTE.—Initial charge applies only when plates are received undeveloped.

TABLE IV.

"U S L" — UNITED STATES LIGHT AND HEATING COMPANY

Type of Cell.	No. of Plates in Cell.	Ampere Hour Capacity.	Normal Discharge Rate.	Charging Rates in Amperes. Start.	Finish.	Initial Charge. Rate in Amperes.	Length of Charge.	Size of Plates.
CB	5	48	12	12	3	4	Until Voltage and Sp. Gr.	4⅞" x 8⅝"
	7	72	18	18	4	5		
	9	96	24	24	6	7		
	11	120	30	30	7	9		
WB	7	84	21	21	5	7	Remain a Maximum for 10 Hrs.	5¾" x 8⅝"
	9	112	28	28	7	9		
	11	140	35	35	8	11		
	13	168	42	42	10	13		
	15	196	49	49	12	15		
	17	224	56	56	14	17		
	19	252	63	63	16	19		
	21	280	70	70	17	21		
CBH	11	120	30	30	7	7		4⅞" x 8⅝"
	13	140	36	36	8	9		
	15	168	42	42	10	11		

UNITED STATES LIGHT AND HEATING COMPANY (CONTINUED)

WBH	11	140	35	35	8	9		5¾" x 8⅝"
	13	168	42	42	10	11		
	15	196	49	49	12	13		
	17	224	56	56	14	15		
	19	252	63	63	15	16		
	21	280	70	70	17	18		
	23	308	77	77	19	20		
	25	336	84	84	21	22		
CBS	11	100	25	25	6	7		4⅞" x 7⅞"
	13	120	30	30	7	8		
	15	140	35	35	8	9		
WBT	9	115	19.25	25	6	7		5¾" x 8⅝"
	11	144	24.00	32	8	9		
	13	174	29.00	38	9	11		
	15	203	33.75	44	11	13		
	17	231	38.50	50	12	15		
	19	261	43.50	56	14	16		
	21	289	48.25	63	16	18		
	23	318	53.00	69	17	20		
	25	348	58.00	75	18	22		
	27	376	62.75	81	20	24		
	29	405	67.50	88	22	26		
	31	435	72.50	94	23	28		

NOTE.—Initial charge applies only when plates are received undeveloped.

"L B A"

TABLE V.

WILLARD STORAGE BATTERY COMPANY

Type of Cell.	No. of Plates in Cell.	Ampere Hour Capacity.	Normal Discharge Rate.	Charging Rates in Amperes. Start.	Finish.	Initial Charge. Rate in Amperes.	Length of Charge.	Size of Plates.
J	5	48	12	10	4	25% of Normal Discharge Rate	Until Voltage and Sp. Gr. Remain a	4 13/16" x 8⅝"
	7	72	18	14.5	6			
	9	96	24	19.0	8			
	11	120	30	23.5	9.5			
K	7	84	21	16.5	7		Maximum for 10 Hrs.	5¾" x 8⅝"
	9	112	28	22	9			
	11	140	35	27.5	11			
	13	168	42	33	13.5			
	15	196	49	38.50	16			
	17	224	56	44	18			
	19	252	63	49.5	20.5			
	21	280	70	55	22.5			
L	7	68	13.5	13	5.5			4 13/16" x 8⅝"
	9	90	18.0	17	7			
	11	113	22.5	21.5	9			
	13	135	27	26	10.5			
	15	158	31.5	30.5	12.0			
	17	180	36.0	35.0	13.5			
	19	202.5	40.5	39.5	15.0			
	21	225.0	45.0	44.0	16.0			

WILLARD STORAGE BATTERY COMPANY (CONTINUED)

M	9	108.0	21.6	19.5	8			5¾" x 8⅝"
	11	135	27.0	24.5	10			
	13	162	32.4	29.5	12			
	15	189	37.8	34.5	14			
	17	216	43.2	39.5	16			
	19	243	48.6	44.5	18			
	21	270	54.0	49.5	20			
	23	297	59.4	54.5	22			
N	7	66	13.2	11.5	4.5			4 13/16" x 8⅝"
	9	80	17.6	15.5	6.5			
	11	110	22	19.5	8.0			
	13	132	26.4	23.5	9.5			
	15	153	30.8	27.5	11.0			
	17	176	35.2	31.5	12.5			
	19	198	39.6	35.5	14.0			
	21	220	44.0	39.5	15.5			
O	7	78.75	15.75	14.0	5			5¾" x 8⅝"
	9	105	21	18.0	7			
	11	131.25	26.25	22.5	9			
	13	157.5	31.5	27.0	11			
	15	183.75	36.75	31.5	13			
	17	210	42.0	36.0	15			
	19	236.25	47.25	40.5	17			
	21	262.5	52.5	45.0	19			
	23	288.75	57.75	49.5	21			
	25	315.0	63.0	54.0	23			
	27	341.25	68.25	58.5	25			

NOTE.—Initial charge applies only when plates are received undeveloped.

CARE OF STORAGE BATTERIES.

General Instructions

APPLICABLE TO ALL STORAGE BATTERIES

Considerable may be and has been written on the subject of *care* and *operation* of *storage batteries* and the whole matter may be summed up in a few words by saying the few things that it is necessary to do and the correct times for doing them. There are certain requisites in the care which cannot be made light of and yet which require a very small amount of time. In the operation of the battery, proper charging is of first consideration since the energy taken from the battery must be replenished for continued operation.

Charging. In charging Storage Batteries, be the make or design what it may, a direct current supply must be used. If alternating current only is available then means must be had for transforming or converting it into direct current. This is a subject which has received careful attention by the manufacturers and will be taken up in detail in Chapter VI.

The common practice in the arrangement of electric vehicle batteries for charging is to connect all the cells in series, the adjacent positive and negative poles being connected, leaving a positive terminal (pole) at one end and a negative terminal at the other unconnected. These are connected respectively to the positive and the negative wires of

the charging circuit in order that the charging current may be forced into the battery through each cell in the same and correct direction, positive plate to negative through the solution. This rule cannot be varied as injury to the battery, with perhaps ruin, will follow. The procedure just described is actually taken care of in the wiring of the vehicle, as received from the manufacturer so that when the trays are installed in the positions indicated and the cells of one tray connected in series to those of the next, it remains only to attach the leads of the vehicle wiring to the end cells.

These are carried to a *charging receptacle* situated on the frame of the vehicle convenient of access. This receptacle is constructed for rigid holding of the *charging plug,* to which are connected the wires from the charging source. The plugs and receptacles used at present are relatively simple and serve the purpose of connecting the charging source to the vehicle battery, preventing accidental or careless contact of the wires of opposite polarity which would cause a short circuit.

At the present time the different forms of charging plug and receptacle supplied by the individual manufacturers of electric vehicles necessitate the public garage carrying an assortment of these to handle such different makes of vehicle as may require charging, either regularly or transient. This inconvenience is obviated by the use of the charging plug adopted as standard by the Electric Vehicle Association of America.

Automatic means for regulating the charging

operation are widely used and are explained in the Chapter on "Charging Apparatus."

Ventilation. The battery should be ventilated as much as possible during charging to carry off the gases liberated, hydrogen and oxygen. To this end the battery compartments should be opened and if, in the case of the lead battery, the vent plugs are accessible they should be removed until the charging is completed.

Naked Flame. The gases liberated, hydrogen and oxygen, will combine explosively when ignited, so that great care should be exercised to keep the compartment free of a naked flame, especially while the cells are gassing or immediately thereafter. An electric light should always be used for inspection.

Electrolyte. Before commencing a charge, the height of the solution should be adjusted to a level, ½" above the tops of the plates, using *distilled water only* for this purpose, *never electrolyte*. How often it will be necessary to add water will depend upon the amount of charging, but will be about once a week, more or less. Where it is especially desired to use water, other than distilled, it is best to send a one quart sample to the manufacturer before running the risk of ruining the battery due to impurities in the water. Electrolyte should only be added where necessitated by sloppage or leakage and then as explained in detail (page 73). Evaporation removes only water and so nothing but water should be added to compensate. It should be stored in clean carboys which have been used for no other purpose and distinctly labelled.

Voltage. The voltage required at the Battery Terminals in order to force the current through the battery is given in the tables on pages 50 and 135, for batteries of a number of cells of both lead and nickel-iron types.

Inasmuch as voltage during charge is considerably higher than that during discharge, the lamps, bell, signal horn or other such devices should not be left on or operated during the charging operations, as the increased voltage will in most cases be sufficient to burn them out. These devices are designed to operate during the discharge only, there being practically no reason for their use at other times.

Temperature. During the charging or discharging operations, described below, the temperature of the battery should at all times be kept below 110° F. The temperature should be measured in those cells near the center of the battery and if there is a tendency to overheat the charging rate should be reduced or if necessary the charging discontinued until the temperature has fallen below the allowable limit. Practically no difficulty will be experienced during discharge except under most extraordinary circumstances.

Charging: Manipulation. Having determined the proper charging rate and the length of time for the charge, the charging apparatus should be put in position for the beginning of the charge, with all switches open. The controller is then placed in the off position, or as demanded in the vehicle in question, some controllers having a special charg-

ing position, or notch. With the total resistance of the rheostat in circuit, the charging plug is placed in the receptacle and the switches closed. The ammeter will show a low value of current, which will increase to the necessary amount as the rheostat handle is revolved. As the charging progresses and the current either increases or decreases the manipulation of the resistance by the movement of the rheostat handle will increase or decrease the charging rate as desired. Usually a movement of the rheostat to the right increases while a movement to the left decreases the current. When the battery is fully charged the operation should be followed in the reverse direction, that is, put all the resistance in, decreasing the current, by moving back the rheostat handle before opening all the switches and removing the charging plug. Making a rule of this practice will avoid short circuits, and burning of contacts.

Discharging. In vehicle batteries the discharging of the cells consists in allowing the current to flow in the reverse direction from that of charge, through a motor which converts the electrical energy into mechanical energy for motion. The amount of current supplied to the motor is regulated by the controller so that starting, stopping, reversing or running at the different speeds may be accomplished with little effort on the part of the driver and without injury to the motor, battery or other parts.

Charging: Out of the Vehicle. When it necessary either for test, after repairs, or with reserve

batteries to charge them out of the vehicle on a bench, then the operation, familiarly known as a *bench charging* or *discharging,* is identical with that described for the battery in the vehicle in nearly all particulars. It admits of ready access to each of the cells during the entire charge and discharge and enables the operator to make complete and full readings of voltage, specific gravity, temperature and such other inspection, as may be required, upon each cell of the number. As this treatment can best be given by placing the battery in a garage where the necessary apparatus and skill is to be had, the details will be given in section II., page 51, devoted to garage practice.

CHAPTER III.

CARE OF LEAD STORAGE BATTERIES.

The instructions in Part I. of this section are intended for the guidance of the individual user of the Electric Vehicle. It is assumed that the individual user is concerned with the primary principles of operation, in order that satisfactory use may be secured with the expenditure of the least time and labor in accomplishing these results in the Private Garage. When it is said that the electric vehicle requires little care and attention, the statement is made seriously but should not be interpreted to mean that it requires no attention whatever. This foreword may seem superfluous to some, but experience has shown that it has been this failure to observe the few simple but important rules that has been responsible for the majority of complaints against the electric car. The storage battery is neither mysterious nor complicated, but being constructed to work, must be kept in condition to do work. The attention required is very moderate indeed, but it is absolutely necessary.

Part II. of this section deals with the Care of Lead Storage Batteries in detail, from the time of their receipt from the manufacturer to the end of their useful life. This material has been collected and prepared to include garage practice so as to be of value to all concerned in the operation and maintenance of vehicle batteries.

To charge a battery completely without excessive gassing, or heating, is the Book of Rules told in one sentence. The remarks which follow explain these three items.

Water. The height of electrolyte to be maintained at all times is one-half (½″) inch above the tops of the plates. This is accomplished by the addition of pure water (preferably distilled) only. The addition of pure water should be made before charging and as often as required by evaporation.

Charging. Direct current only must be used for charging. Where alternating current only is available suitable apparatus (Chapter VI.) must be used to convert it to direct current. The polarity must be correct, that is, the positive terminal of the battery must be connected to the positive terminal of the charging supply circuit.

As it is necessary to ventilate the battery during charge, the battery compartment should be opened and the soft rubber vent plugs removed from the cells if accessible.

Under ordinary conditions it is not necessary to charge the battery more often than once a week unless over fifty (50%) per cent. of its capacity has been discharged. The battery should never be allowed to stand in a discharged condition.

The limitations imposed at any and all points of the charging operation are those of gassing of the cells and temperature of the electrolyte. Excessive gassing must not be permitted. Under all ordinary conditions begin the charge at the starting rate or

higher of the two rates given on the name plate or in Tables I-V, and reduce the current in several steps, avoiding gassing and high temperature, until the finishing rate has been reached. Continue the charge at this rate until the voltage and specific gravity have risen to maximum values. At this point the cells will be gassing freely. It is better to stop the regular charge too soon than to overcharge. It is permissible to begin the charge at a higher rate, but care must be exercised to reduce the current should the cells gas or the temperature rise above the allowable limit.

Where any device or means is used in regulating the charge, especially as to the length of time, it should be adjusted so that a uniform gassing at the finishing rate, indicating the end of a regular charge, will be produced. This amount varies somewhat but is between five and fifteen per cent. more than the number of ampere-hours taken from the battery on the preceding discharge. This statement applies to ampere-hour meters, time clocks and rectifiers fitted with an automatic attachment.

Quick Charging or "Boosting." At times where conditions may require the greatest possible amount of charge in the time available, the charge may be begun at a high rate, which must be reduced according as the gassing and temperature increase. The temperature must never be allowed to exceed 110° F.

Overcharge. Bi-weekly at the end of the regular charge continue the charging at a rate not greater than the finishing rate until the specific gravity

has stopped rising. When hourly gravity readings on the pilot cell are alike for four successive readings, then the overcharge may be discontinued.

Discharge. The battery should not be discharged below 1.7 volts per cell at its normal service rate and should not be allowed to stand in a discharged condition. If the full charge cannot be immediately given it should be put on for a partial charge. Beyond these limits the battery may be discharged as the requirements of the service demand, however severe it may be.

Gassing. In charging the battery, the rate at which the cells give off gas, is the determining feature. Violent gassing should at no time be permitted and whenever the gassing exceeds a very moderate amount, the charging rate should be lowered even though the length of time required for a charge be greater. Disregard of this precaution is probably responsible for the shortening of the life of most batteries.

Temperature. The temperature of the electrolyte should be kept below 100° F. and never be allowed to rise above 110° F. during charge. If necessary, the rate should be decreased or charging temporarily discontinued until the cell has returned to a normal temperature.

Electrolyte. The electrolyte should be maintained at the proper level by the addition of pure water. *Never add acid.*

At least once a month at the completion of the overcharge, readings of specific gravity should be recorded on all cells. Should any cell have a read-

ing higher than 1.300 or lower than 1.250 when fully charged, it is evidence of trouble, such as a leaky jar, partial short circuit, or sloppage. The trouble should be found and remedied immediately. See "Electrolyte," page 73.

The specific gravity of the electrolyte should at no time be in excess of 1.300. Should this condition be found, some of the electrolyte should be withdrawn and water added to reduce the gravity of the solution. On the other hand, should the reading of any cell be less than 1.250, it may point to insufficient charging. If all of the cells have gradually decreased in specific gravity to below 1.250 and the cause not be insufficient charging, or lost electrolyte replaced by water, then it is safe to say that sediment has accumulated in the bottom of the jars, the battery should then be placed in the hands of a competent battery man for inspection.

The "Pilot Cell" referred to above is a convenient cell of the number which may be taken as representing the state of charge of the battery. There is a variation of approximately one hundred (100) points (0.100) in specific gravity so that the reading of specific gravity at any time compared with the reading when fully charged will give very nearly the exact extent of discharge. The point at which the specific gravity reading of the pilot cell fails to increase and the cells gas freely may be considered the end of a regular charge.

Battery Out of Service. If the battery is to stand idle for any length of time, an overcharge

should be given immediately before and immediately after the period of standing. Should this extend over several months, then a freshening charge should be given monthly at the finishing rate. If the idle period is to exceed four months or the treatment prescribed cannot be given, then the battery should be sent to a garage for the proper care.

Caution. Keep naked flames away from the battery, both while charging and immediately after charging as the gases liberated are explosive. Ventilation is required to dispose of them.

For handling the water or acid, only clean glass or earthenware should be used.

The battery should be kept in a clean condition and no foreign material allowed to find its way into the cells.

POINTS TO BE REMEMBERED IN THE CARE OF LEAD BATTERIES.

Unnecessary Charging. Is wasteful of current and uses up the life of the battery.

Standing Discharged. Is to be avoided in all cases as the succeeding charge would otherwise have to be for a longer time than usual in order to bring the battery into normal condition.

Adding Water. Pure water (preferably distilled) only should be used and added before charging. Under no condition put in acid unless distinctly specified.

Kind of Current. Use direct current only, connecting the positive (+) terminal of the battery to the positive pole of supply source.

TABLE VI.

CHARGING VOLTAGES FOR LEAD BATTERIES.

No. of Cells.	VOLTS AT Start.	Finish.	No. of Cells.	VOLTS AT Start.	Finish.
12	26	31	32	69	81
14	30	36	34	73	87
16	34	41	36	77	92
18	39	46	38	82	97
20	43	51	40	86	102
22	47	56	42	90	107
24	52	61	44	95	112
26	56	66	46	100	117
28	60	71	48	105	123
30	64	76	50	110	128

These voltages are approximate and are intended for guidance only.

A battery when cold or new will show a higher voltage than an old one or at high temperature.

It is not safe to regard a fixed voltage as the end of the charge, but a maximum voltage for the battery in question.

Ventilation. Open the battery compartment during charge and if convenient remove vent plugs.

The above voltages are approximate and are intended for guidance only.

A battery when cold or new will show a higher voltage than an old one or at high temperature.

It is not safe to regard a fixed voltage as the end of the charge, but a maximum voltage for the battery in question.

Gassing. Charge only until moderate amount of gassing is produced and not longer as it is wasteful both of current and battery.

Temperature. During charge do not allow the temperature to exceed 110° F. Either reduce the current or discontinue the charge temporarily, if necessary.

Caution. Keep naked flames away from the battery in order that the gasses may not be ignited.

PART II.

Unpacking. The crates or boxes containing the trays should be handled carefully and kept right

side up to avoid spilling the electrolyte. They should be opened from the top and if necessary, one of the sides taken off for the removal of heavy trays. Care should be exercised in the handling of tools so that the jars may not be cracked. The trays and cells should then be cleaned off thoroughly and each cell examined for any possible damage. All the connections should be tight and clean as a loose connection would be liable to cause reduction in speed and mileage and eventually burn off. Should a loose connection be found, it should be lead burned or if that cannot be done at the time, then a temporary repair can be made by soldering but should be lead burned as soon as possible.

Should any broken or cracked jars be found, they should he replaced immediately. If there are no extra jars available, then the element should be removed from the broken jar and placed in a glass or earthenware vessel in acid of approximately 1.275 sp. gr. The plates must not be allowed to dry in air as it would require a very long charge to bring them back to a healthy condition. If the electrolyte level is lower than ½ inch above the tops of the plates, due to spilling and not to broken jars, then solution should be added to the correct level.

Batteries when shipped in the wet condition are shipped fully charged and require a freshening charge at the finishing rate of the make of battery in question, until all cells gas freely, before being placed in service.

When cells are shipped in the dry condition, they may either be assembled ready for the addition of

electrolyte and the developing charge or as plates to be burned to the straps and assembled in the cells. As both of these shipments would require the developing charge they cannot be placed in service as can the batteries received in the wet state.

ASSEMBLING AND PUTTING NEW BATTERIES INTO CONDITION.

The parts must be unpacked, cleaned and examined carefully to see that they are in good condition and free from foreign material.

The plates must be grouped, that is, lead burned to the straps. This must be done by an experienced lead burner and when finished must be inspected to see that no lead has run down between the plates.

The plate lugs should be scraped clean and bright by a scraper of the kind used by a plumber and the plates for one group placed in a burning rack or burning box as shown in (Fig. 12). Across the top of this box is fitted a piece of iron in which notches are cut correctly spacing the plate lugs. (Fig. 13.) The strap is then placed over the lugs and burned to them. The details of this assembly, as to the distances between plates and from the top of the plate to the strap, will depend upon the particular type and make of battery in hand. After the plates have been assembled into groups, the latter should be combined ready for the insertion of the separators. This is done by placing a perforated hard rubber sheet separator against the grooved side of a wooden separator. These pairs are then inserted between the surfaces of each positive and negative plate so that the flat side of the wooden separator is against the negative plate and the hard rubber sheet against the positive plate in each case. Should a separator, either wood or rubber, be broken while being placed in position, it should be discarded for a new one. No separators are placed between the surface of the negative plate

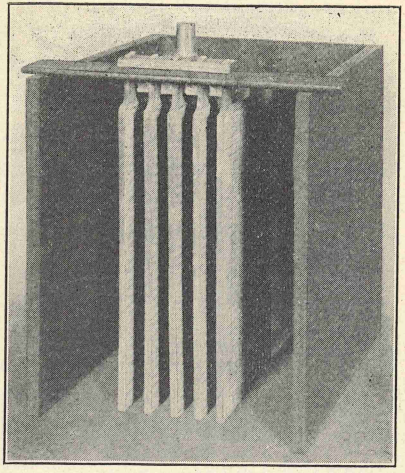


Fig. 12—Burning Box.

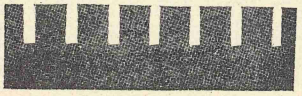


Fig. 13—Burning Iron. For assembling elements with top or high burned straps.

and the containing jar. It is well to be careful that the edges of the separators are flush with the bottom of the plates so that contact between the plates may be avoided. The plates may be gently pressed together and are then ready to be placed in the jar. With the element lying horizontally on the bench, the top of the jar, bridges crosswise with the plates, is placed around the element, being started carefully so that no edge of the plates or separators may catch on the rim of the jar. Only jars in good condition and thoroughly washed should be used.

It is necessary to secure the separators firmly in position so that they may not have an opportunity to float up from between the plates, allowing the latter to touch. For this purpose "hold downs" are used, Fig. 6. When the groups are assembled with pillar straps, then a fin projects down sufficiently to keep the separators in place. With "L" or "T" straps, however, blocks of rubber or glass are used to keep the separators in a rigid position.

The cells are then ready for the acid, assembly in the trays and connections, so that the developing charge may be started. In several factories, the practice is to place the cells on a bench, instead of in the regular trays, in order that they may be kept cool by circulation of air during the initial charge. Where there is any tendency for the containing jars to warp or bulge from the heat, it is preferable to assemble the cells in the trays before beginning the developing charge as, otherwise, they could not be readily assembled in the trays. When the developing charge has been completed, the acid may

be poured out and acid the proper strength immediately added to the correct level.

In some cases, where considerable developing is done, arrangements are made so that the jars may be placed in a tank through which cooling water may be circulated around the jars. An electric fan also helps considerably in keeping down the temperature of the cells during charging by circulating the air.

When preparations are completed, then the electrolyte of about 1.210 specific gravity should be added to the cells to a level of ½ inch above the plates. The acid should not be above atmospheric temperature as the mere addition of acid to the cell will cause heating. It is necessary for the temperature of the cell to decrease to a normal value, such as that of the room, before the initial charge can be begun. As this may take from 10 to 15 hours, it is generally advisable to add the electrolyte in the afternoon so that the cells may be allowed to cool over night and be ready for developing the following morning. Also, the acid will combine with the water in the separators so that the cells should stand for at least 12 hours before the initial charge is begun.

Having made the necessary connections, the charging should be begun at the rate given in the table and continued for the length of time necessary to charge the plates beyond any question of doubt. As the plates are received dry, and may have been standing in a dry condition for some length of time, they are in a somewhat sulphated

state and need a long initial or developing charge to remove the sulphate. All of it must be removed by charging since if it is not removed at this time it will probably remain permanently.

Cells received from the manufacturer assembled and ready for developing are sometimes provided with hard rubber separators instead of with wooden separators because wooden separators unless maintained in a moist condition would warp and crack and be unsuited for service. To the cell thus assembled, it is necessary only to add acid of 1.170 specific gravity as described and continue with the initial charge.

The wooden separators are specially treated by the manufacturers to remove impurities, especially organic substances, which would greatly reduce the life of the plates. They are generally shipped in wet sawdust and should be kept moist by frequent sprinkling with water. If they are to be kept for any length of time they should be placed in a tank of pure water slightly acidulated with sulphuric acid.

The amount of charge necessary in developing a new battery will amount to about six times the rated ampere-hour discharge capacity, but must be governed solely by the indication of completeness of charge with very little gassing and not exceeding a temperature of 100° F. Should the temperature, during any part of the charge, rise above 110°, the charging should be temporarily discontinued until the normal temperature has been resumed. The charge should continue without interruption if possible until the voltage and specific

gravity have reached a maximum. It is well to continue the charging for about ten hours beyond the point where these quantities no longer rise, in order that surety of completeness may be obtained. In order to obtain true density readings, since the specific gravity varies with the temperature, they must be corrected for the temperature changes on the basis of .001 specific gravity for each rise of 3° F., the standard being 1.280 at 80° F. Table No. 7, page 80, gives these corrections at a glance for the entire range ordinarily encountered in vehicle batteries.

After the charge has been completed, the electrolyte in each cell should be tested and the density adjusted to what corresponds to 1.280 at 80° F., maintaining the proper solution level of ½" above the plates. The cells will usually increase in capacity for a number of cycles of charge and discharge during the early life of the battery, although the most rapid period of increase will be during the first 10 cycles. Should a high discharge capacity be required immediately when the battery is put into service, then several test runs of charge and discharge should be given before putting the battery into commission, in order to work up the capacity. In general it may be considered good practice to make a few test discharges after the developing charge, taking careful readings of the voltage and specific gravity of each cell in order to make sure that all cells have been developed evenly and sufficiently.

Assuming that the cells have been tested and

found ready for service, they are then ready to be assembled in the trays. Before doing this, however, inspection should be made to see that they have been correctly assembled with separators in proper position and with no lead "flow downs" lodged on top or between the plates. When placed in position in the trays, the connections between cells should be carefully lead burned to the full depth of the straps and covers placed in position. If the cells are to be sealed, this should be done before the cells are placed in the trays and burned together. The jar and cover must be clean and dry for the compound to adhere. If acid or water remains on the hard rubber it will not stick. The sealing compound may be softened by being placed in a vessel heated over a moderate flame or the flame may be applied directly over the compound. When almost liquid it may be readily applied by a hot putty knife. For pressing into final position and finishing the sealing the putty knife should itself be heated in the flame. The sealing compound must neither melt at the working temperatures of the battery nor crack at low temperatures, so that the compounds supplied by the manufacturers should be used rather than untried material.

Cleanliness. It is necessary to maintain the cells, trays, terminals, connections and the battery space in the vehicle dry and free of electrolyte as a great many of the difficulties encountered in ordinary use can be traced to neglect. Should the electrolyte be slopped over the outsides of the jars and

connectors or metal fittings, corrosion will result which will ultimately create loss of capacity.

CHARGING.

Service Charging. In charging, direct current only can be used in order to effect the chemical changes. Should alternating current only be available, then a suitable rectifying device must be used to convert the alternating current to direct current. These devices are described under "Charging Apparatus," Chapter VI.

Before charging is begun pure water (preferably distilled) should be added to compensate for evaporation, bringing the level of the electrolyte to one-half inch above the tops of the plates.

As the normal condition of the plates in the discharged condition, is the lead sulphate state, the change to lead peroxide and spongy lead in the positive and negative plates, respectively, should be accomplished without wasting current or wearing the plates too rapidly. If the battery is steadily undercharged then the plates will gradually accumulate sulphate which will be evidenced by low specific gravity and low capacity. The longer the sulphate remains in the plate the more difficult it is to remove, that is, the more charging will be necessary. The desire therefore in bringing the battery to a fully charged condition is to send all of the sulphate from the plates back into the acid. In so doing, the current must not be so great as to cause excessive gassing since that would tear small particles of active material from the plate

and thus shorten its life. Moderate gassing is permissible and at the proper rate, as explained later, is an evidence of the charged condition. The temperature must be kept within moderate limits also so that the chemical action may not be too rapid. It is recommended that the charging be regulated so that temperatures in excess of 110° F. will not be reached. If necessary reduce the current or discontinue charging until the battery has returned to safe limits.

With the above in mind, it can readily be understood that when a battery has been fully discharged it should not be allowed to remain in that condition since the sulphate would be hard to reduce, taking an abnormal amount of charging to restore to healthy condition.

From this it is evident that a battery may be charged at any rate, no matter how large or small, as long as the temperature does not rise above 110° F. and the gassing does not become excessive. Under ordinary circumstances the most satisfactory results may be obtained by observing the following rules.

Begin the charge at the starting rate, given in Tables I-V, and reduce the current in several steps, avoiding gassing and high temperature, until the finishing rate has been reached. Continue the charge at this rate until the voltage and specific gravity have risen to a maximum value. At this point the cells will be gassing freely. It is better to stop the regular charge too soon than to continue too long. It is necessary to add be-

tween 5 and 15% more ampere hours in charging than have been taken out on the previous discharge.

The voltage of the battery will rise during the charge to a maximum value, which is not necessarily, and which probably will not be, a fixed value. It will change with the age of the plates, the strength of the electrolyte and the temperature. New plates will have a higher final voltage than old plates and both will give higher final voltage with low temperature. These changes render charging by voltage alone as a standard a very unreliable process, so that specific gravity and gassing, with voltage as a check, give the best results. Providing that the battery is given the required care, the action in all cells will be practically uniform and one cell, conveniently located, may be taken as indicative of the others. Readings of specific gravity taken on this pilot cell therefore afford a simple and easy means of keeping the charging within bounds. The gravity varies slightly with the temperature and Table 7, page 80, is given so that corrections may be easily made, to the density of 80° F.

While the battery should not be allowed to stand in a discharged condition, it should not be charged unless necessary. If less than 50% of the capacity has been discharged then a charge should not be given unless the subsequent discharge will require more than the capacity available. To run the car a comparatively small percentage of its mileage and then give approximately a full charge is evi-

dently a waste of current and battery. A set of plates is capable of a given number of charges during its useful life. The number of cycles of charge and discharge depends upon the conditions of service, so that wasteful charging dissipates not only current uselessly but plate life also.

A very convenient method of automatically recording and calculating the charging necessary is accomplished by an instrument known as an Ampere-Hour Meter, Fig. 14. This instrument is furnished with a dial, and hand revolving in a counter-clockwise manner on charge, and clockwise manner on discharge. (This order is reversed by some vehicle manufacturers.) During the discharge a glance at the meter gives a direct reading of the discharge capacity used, so that knowing the total discharge capacity available, the amount remaining is readily given. The total available ampere hour capacity divided by the number of miles under average conditions of driving will give the ampere hours per mile. This figure depends upon the condition of vehicle, roads and load carried. Taken under normal conditions, however, this figure divided into the capacity gives the average mileage obtainable on one charge of the battery. If the capacity be 120 ampere hours and the ampere hours per mile be 3, then approximately 40 miles is available per charge of the battery.

During charge the pointer revolves counter-clockwise until it reaches the vertical position where it remains against a stop, showing full charge. An adjustment is provided allowing the charge to be

made from 0 to 30% greater than the discharge. This setting is arbitrary and depends upon the service conditions. Additional wiring is provided so that a circuit breaker may be closed when the pointer reaches the stop, disconnecting the battery from the charging circuit.

This feature is very convenient for effecting

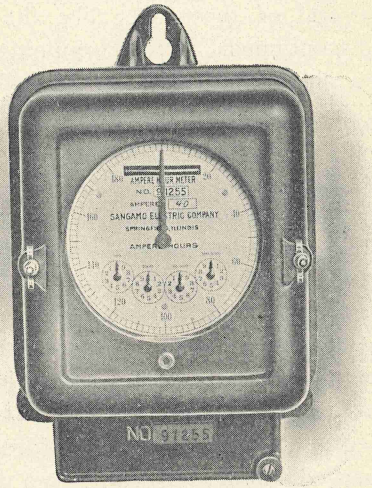


Fig. 14—Ampere-Hour Meter.

the desired charge with little waste and minimum attendance as well as for discontinuing a charge during the night.

OVERCHARGE.

Under the head of charging the instruction was given to discontinue the charge too soon rather than to charge too long. Under this heading the

instruction is to overcharge too long rather than too little. The reason for this is that the overcharge is designed to bring each cell of the battery to a fully charged condition. This is accomplished by continuing a regular charge at the finishing rate three or four hours after the pilot cell has reached a maximum of specific gravity and voltage readings. Hourly readings should be taken. When several of these are alike the overcharge may be discontinued. Before beginning this charge inspection should be made of all cells and pure water added to bring the solution to the correct level of one-half inch above tops of plates.

The regular charge should be discontinued when the battery is approximately charged so that no harm may be done by constantly overcharging. Assuming that the plates are not fully charged each time, the capacity will decrease gradually as indicated by the lower specific gravity readings. It is necessary to send the sulphate held in the plates back into the solution, recovering the full capacity, by the periodic overcharge. Therefore, should the car be charged and discharged daily, a weekly overcharge would be most satisfactory, while on the other hand if the mileage required be small and the regular charges infrequent then a bi-weekly overcharge is sufficient to keep the plates in healthy condition.

When a battery is to remain idle for any length of time, a freshening overcharge should be given at least monthly and preferably bi-weekly while not in service. Should the period be for over four

months or facilities for this charge not available then the battery should be taken apart and stored dry as explained under "Taking Out of Commission," page 96.

CHARGING OVERNIGHT.

There are a number of applications in which it is impossible for attention to be given the battery during charge, such as, charging overnight or when no attendance can be given. In this case the battery may be placed on charge at a rate never more than 2/3 of its regular "starting rate" and allowed to remain on charge, the current gradually decreasing until discontinued either by hand or by an automatic device. The number of ampere-hours required should be estimated by adding 10% to the capacity in ampere-hours taken from the battery on its previous discharge. Thus the number of ampere-hours required to fully charge the battery, divided by the number of hours available, will give the average current for the charge. When charging from a constant potential circuit, the current will decrease gradually throughout the charge. This is most rapid at the beginning due to the heating of the charging rheostat. For this reason the rate may be set two or three amperes higher than the average current at the beginning, but a rate exceeding 2/3 of the "starting rate" should not be used unless attention can be given.

The limiting conditions of charging in this manner are gassing and temperature and what has been said in the previous paragraphs is also true

in this case. Excessive gassing or high temperatures must not be permitted so that it will be necessary to give frequent attention, observing the temperature and gassing during the first few periods of charge, in order that the results may be obtained without running the risk of ruining the battery. After these experimental charges, conditions will be known approximately and a close estimate can be arrived at for subsequent unattended charges.

There are a number of automatic means for regulating charging. The ampere-hour meter has been described. When wired to a circuit breaker it discontinues the charge when the required number of ampere hours have been supplied. The hand on its dial rotates to its zero position making a contact which closes the trip circuit of the circuit breaker.

A time clock may also be secured that will open the circuit at a predetermined time. Mercury Arc Rectifiers are furnished with attachments which not only restore the arc in case the service has been discontinued, but which also cut-out when a certain maximum voltage has been reached. None of these devices control the rate of current during the charge so that while the time during which the charge lasts may be correct, the rate of charge depends wholly upon the attendant, and should be kept as low as possible in order that the limitations of temperature and gassing may not be exceeded. Whenever possible, attention should be given to obviate any damage from excessive heating or gassing.

BOOSTING OR EMERGENCY CHARGING.

Charging of this nature should be resorted to only when conditions make it imperative and not as a standard practice. If the vehicle requires a boost in order to reach its garage or cover its route, after a trip which has taken practically all of its available capacity, then this emergency charging is certainly advisable. During certain times of the year the road conditions or extra heavy loads make an extra charge necessary. This may be given either when the battery has been fully discharged or during a noon hour or similar period of rest. The advantage of the noon hour period is that no unnecessary time need be spent, but on the other hand, the charge will be limited to approximately one hour. In the preceding paragraphs, emphasis was laid upon the fact that the life of the battery depends upon the number of charges it receives. So that with this in mind, boosting should not be done unless absolutely required. If it is known that the vehicle will negotiate its route without danger of falling short of mileage, then it should not be boosted while being loaded or standing excepting in conformity with the above. The proper size battery should be installed originally to correctly meet the requirements of the service. If this is done it is only the unusual conditions of service which will make a boost necessary.

In giving a charge at a high rate, the limiting features are temperature and gassing. The temperature must not be allowed to rise, under any circumstances, above 110° F. and should be kept

as much below 100° F. as possible. In the summer it is evident that this will limit this method of charging. The gassing should at no time be permitted to be excessive and it is well to keep it a minimum. The more fully the battery is discharged the higher may be the starting rate of the boost so that a fully discharged battery may receive the same amount of charge in a shorter time than a battery which has been but partly discharged.

The standard instructions for giving a rapid charge are to start the charge at a rate 50% above the normal charging rate, gradually reducing the current step by step until the finishing rate is reached, when the charging may proceed as described under "normal" service charging. The limits of gassing and temperature must be very rigidly observed or damage will result. The indications of the extent of charge are voltage, specific gravity and gassing as have been explained.

A method for boosting which has been developed and recommended by several prominent storage battery engineers, making use of the ampere-hour meter is as follows: Make the boosting rate in amperes equal to the quotient of the ampere-hours discharged from the battery divided by one plus the time available for boosting in hours. That is, if the ampere-hour meter shows 200 ampere-hours discharged and one hour available for charging

then the rate would be $\frac{200}{1+1} = 100$ amperes

for one hour. If but 15 minutes should be available then the current could be as high as $\frac{200}{1+.25}$ = 160 amperes. It is said that the gassing point will just be approached at the end of the specified time, when the rates are determined by the above rule.

Experience has also shown that when a battery is placed upon a constant potential circuit of 2.3 to 2.35 volts per cell without intervening resistance, that the charging rate in amperes will then very nearly equal the state of discharge in ampere-hours at any time.

Having in mind what has been said under this heading, it is evident that a charge may be begun at any current rate, several times the normal charging rate if necessary and reduced according as the gassing and temperature dictate. This method is very convenient and will admit of very flexible operation of the electric vehicle, but it is recommended for use only in the hands of competent attendants.

CHARGING OUT OF THE VEHICLE.

When it is necessary either for test, after repairs, or with reserve batteries to charge them out of the vehicle on a bench, then the operation familiarly known as a "Bench Charging" or "Discharging" is identical with that described for the battery in the vehicle in nearly all particulars. It admits of ready access to each of the cells during the en-

tire charge and discharge and enables the operator to make complete and full readings of voltage, specific gravity, temperature and such other inspection, as may be required, upon each cell of the number.

The connections from the battery to the charging source are not effected by means of the charging plug and receptacle, as the battery is disconnected from the vehicle wiring. Should there be necessity for considerable bench charging then it

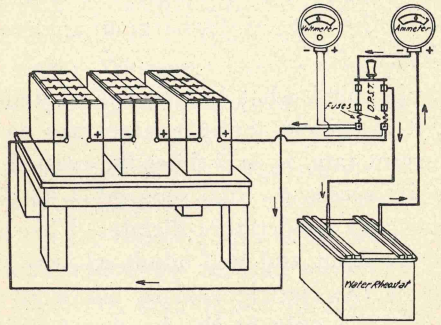


Fig. 15B—Battery Connected for Test Discharge.

might be convenient to have an extra receptacle the terminals of which would admit of rapid but secure fastening to the battery terminals.

When the battery is in the vehicle it is discharged by passing the current through the motor, which does useful work, such as propelling the vehicle. In this case, however, the current is to be dissipated in the form of heat by passing the current through a suitable resistance or rheostat. The positive and negative terminals are connected (Fig. 15) through the rheostat or suitable resistance and an ammeter. The ammeter indicates the current rate of discharging in the same manner as that of charge. The rheostat used in charging will not have sufficient resistance for discharging the battery especially at the beginning of the discharge. When the voltage is high, additional resistance must be placed in series.

One that is very convenient and easily constructed is what is known as a Water Resistance. This is constructed by making use of a wooden tub or half-barrel. Two wooden sticks or rods are laid parallel across the top of the barrel and from them are suspended two metal plates (iron grids or lead iron) parallel to each other One wire from the battery is connected to one of these plates through one pole of a double pole switch, the other plate is connected through the ammeter to the other pole of the switch and thence to the

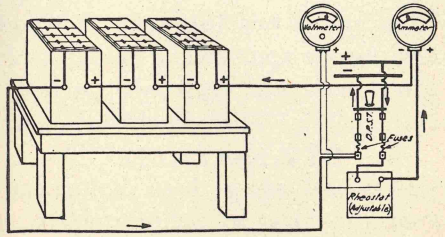


Fig. 15A—Battery Connected for Charging when Out of the Vehicle.

other battery terminal. Before starting to discharge, all the resistance should be put in the circuit in the charging rheostat ordinarily used and the plates in the tub separated as far as possible. The tub can then be filled with clean water and the switch closed.

Small quantities of sulphuric acid added to the water from time to time will increase the current and will serve in the same way as moving the plates toward each other. It is preferable to have the plates remain fixed and to add acid, increasing the conductivity of the solution as short circuit between the plates will be less liable to result. This resistance in series with the regular resistance will give easy and fine regulation of the current. The diagram shows the method of connecting the parts and taking the readings.

In making the connections referred to, the wires or cables should be of such size as not to heat unduly at the maximum current of discharge. The size of wire used in the vehicle is sufficiently large.

INSPECTION.

An inspection should take place at least every month in order that slight troubles may be remedied before they become serious and serious ones remedied immediately. If the battery compartment is constructed so that the inspection may take place with the trays in the vehicle then it is not necessary to remove them. If this is not the case, however, then it would be necessary to disconnect the end leads to the controller and slide the trays out. A low truck on rollers is found to be very convenient for this work as the truck can be run up along side or in front of the battery compartment and the tray placed upon it. In fact, an adjustable platform truck is manufactured for this service. The rubber plugs should be removed so that the tops of the plates may be seen. The level of the electrolyte, which should be one-half inch above the plates, should be determined by means of a piece of one-quarter inch glass tubing or by inserting a clean strip of wool or hard rubber. If the level is not correct it should be made so by adding pure water. The connectors between the cells should be examined and if any are found to be weak, loose or broken they should be repaired. After cleaning, the trays are then ready to be placed in commission.

ELECTROLYTE

The electrolyte used in the lead type cell is a mixture of pure sulphuric acid and pure water. This mixture, known as dilute sulphuric acid, should be chemically pure, but no harm will result if cer-

tain chemicals are present which do not affect the activity of the cell. Impurities such as iron, copper, platinum, mercury, arsenic, chlorine, nitric acid and acetic acid must never be present.

Always pour acid into water, never water into acid.

When acid and water are combined, a chemical reaction takes place and considerable heat is developed, the amount of heat depends upon the relative proportion of acid and water. Should a small quantity of water be poured into a vessel of acid, the water would immediately be turned explosively into steam with the result that a part of the mixture of water and acid would fly up from the vessel and probably seriously injure the face and hands of the operator. Ordinarily it is more advisable for the user to purchase electrolyte ready for use or if wanted in quantity, acid of 1.400 specific gravity will usually be found of sufficient strength.

Owing to the heat generated it is necessary to allow the solution to cool before taking the specific gravity of the mixture inasmuch as the density changes with the temperature. By referring to Table 7, on page 80, the real density at any temperature may be found and compared with that at a standard temperature of 80° F. This change in specific gravity is due to temperature and is a physical change only. However, when electrolyte is used in the active cell then another change takes place which has already been described, that is, a variation in density due to chemical change, the acid being absorbed by the plates. The acid itself

is broken up, the sulphate part combining with the plates and the hydrogen part combining with the oxygen set free to form water in the electrolyte.

Thus the specific gravity of the cell will decrease as the cell is discharged and increase upon charge, returning to the original value upon charging to the same extent as originally, making allowance for the temperature change. The density increases until all the acid is out of the plates. In some cases where the plates are badly sulphated, that is where the sulphate has hardened, excessive charging will be required to remove it. During such a charge the rise in gravity will be very slow.

This specific gravity or density is measured by a simple instrument known as a hydrometer. This very useful accessory is constructed of glass weighted at the bottom with lead shot and possesses a calibrated scale so that when immersed in the liquid, the reading of the scale at the surface of the solution is the specific gravity of the electrolyte.

For convenience in making this reading the hydrometer is usually placed in a second glass tube of sufficient diameter to allow the hydrometer to float. This hydrometer syringe furnished with a pure rubber tube at the lower end and a rubber bulb at the upper end permits electrolyte to be drawn from the cell into the barrel and to float the hydrometer. In this manner the gravity readings of the electrolyte in all the cells of the battery may be readily and quickly determined. For ordinary charging it is necessary to read the gravity of a few cells only,

"pilot cells," assuming that these are characteristic of the battery. At the inspection and reforming periods, however, each cell should be carefully gone over.

The amount of the electrolyte required in the cells depends upon the size of the containing jar and the number and size of plates and is usually given in the manufacturer's catalogue. However, it is a simple matter to remember that whatever this size may be, the electrolyte in any cell should be one-half inch above the tops of the plates so that sufficient may be available for evaporation or sloppage without exposing any of the plate surfaces, which is injurious.

The specific gravity, when the cell is fully charged, will be approximately 1.260 to 1.280, depending upon the condition of the cell and temperature; when the cell is considered discharged, the gravity will have fallen from 1.160 to 1.180 or, in other words, a drop of about 100 points will have occurred owing to the removal of sulphuric acid by the plates. From this it can be readily understood that the amount of charge can be at once found by taking hydrometer readings, knowing the upper and lower limits for the particular battery in question and correcting for temperature change.

Throughout the instructions emphasis has been laid upon the fact that distilled water only should be used to replace evaporation. The reason for this is, that adding acid would change the gravity of the cell and so there would be no check upon its condition with the effect that the strength of the

solution would gradually become too great for satisfactory results, sulphating the plates and reducing the efficiency of the cell. It is obvious that by changing the gravity through such means that no indication of the state of charge would be reliable. High density when thus given will shorten the life of the battery.

Should a leaky cell be found it would be necessary to place the element in a new jar and replace the electrolyte with that of the same gravity as the adjoining cells of the battery. After charging at the "finishing" rate until the gravity of the leaky cell has ceased to rise, the density should be finally adjusted to the correct point (that of the adjoining cells).

After the overcharge has been given, gravity readings should be taken of all cells of the battery. If the battery has received the proper overcharge and it is evident that low specific gravity in any cell is due to sloppage or spilling and not undercharging, then some of the electrolyte should be withdrawn and acid added to bring the gravity up to that of the other cells. If the specific gravity be higher than 1.300 in any cell it should be reduced by withdrawing electrolyte and adding pure water. This "equalizing" should be done only when low density is not due to insufficient charging, because the gravity is the indicator, and tampering with the indicator will only give temporary, misleading results.

Should there be doubt of the purity of the water or electrolyte or indications of trouble from them,

then samples of one quart of water or four ounces of solution should be sent to the manufacturer for test.

Electrolyte—Low Cells. Cells low in capacity are evidenced by low specific gravity after prolonged charging. There are many causes for low cells, among which may be mentioned, insufficient charging, leaky jar, loss of electrolyte by spilling, broken parts or presence of foreign material. The remedies for these may be divided into three classes.

The first and simplest is to treat the cell electrically, by prolonged charging at a low rate, until the gravity and voltage reach a maximum. This charge should be too long rather than too short, for if not complete the trouble will be only temporarily removed.

In the case of leaky jars it is necessary only to replace the jar and give a long charge at a low rate, after which the gravity should be adjusted to the same value as that of the adjoining cells. When water has been added to replace spilled electrolyte then the gravity may be equalized by adding acid enough to bring up the density. If foreign material has found its way into the solution, then the solution should be renewed and the water used to replace evaporation tested for impurities as explained under "Electrolyte." Salt and iron are most likely to find their way into the cells. Salt will be indicated by the offensive odor of the chlorine gas given off during charging and iron by the dirty yellow

color given to the positive plates. Similar evidences are given by other impurities.

If these are found present, the cell should be dismantled irrespective of its state of charge or discharge, as explained under "Sediment," washed and reassembled with pure electrolyte of the same gravity as that removed and new wood separators and given several charges and discharges. After these and while discharged, again take the cell apart, rinse the parts well and reassemble with new electrolyte of 1.200 specific gravity. Then give a long charge. All precautions should be taken as detailed under "Sediment," p. 87.

Taking the cell apart to inspect for sediment, contition of separators, short circuits between plates, etc., includes only dismantling the cell and reassembling into the original condition as nearly as possible.

When it is necessary for inspection or in testing to determine the cell voltages throughout the charge and discharge periods, the readings are taken with a low reading voltmeter. An accurate instrument should be used for this purpose and should be returned to the manufacturer or competent laboratory for calibration at least twice a year.

Probably the most convenient form of voltmeter is one which has a double scale, one scale reading 0 to 150 volts for determining a complete battery or line voltage and the other scale reading 0 to 3 volts. Where there is sufficient use for a low reading voltmeter, an instrument with but one (low reading)

TABLE VII.

TEMPERATURE CORRECTION FOR SPECIFIC GRAVITY OF ELECTROLYTE

30°	40°	50°	60°	70°	80°	90°	100°	100°
1.317	1.313	1.310	1.307	1.303	1.300	1.297	1.293	1.290
12	08	05	02	1.298	1.295	92	88	85
07	03	00	1.297	93	90	87	83	80
02	1.298	1.295	92	88	85	82	78	75
1.297	93	90	87	83	80	77	73	70
92	88	85	82	78	75	72	68	65
87	83	80	77	73	70	67	63	60
82	78	75	72	68	65	62	58	55
77	73	70	67	63	60	57	53	50
72	68	65	62	58	55	52	48	45
67	63	60	57	53	50	47	43	40
62	58	55	52	48	45	42	38	35
57	53	50	47	43	40	37	33	30
52	48	45	42	38	35	32	28	25
47	43	40	37	33	30	27	23	20
42	38	35	32	28	25	22	18	15
37	33	30	27	23	20	17	13	10
32	28	25	22	18	15	12	08	05
27	23	20	17	13	10	07	1.203	1.200
22	18	15	12	08	05	1.202	98	95
17	13	10	07	1.203	1.200	97	93	90
12	08	05	1.202	98	95	92	88	85
07	1.203	1.200	97	93	90	87	83	80
1.202	98	95	92	88	85	82	78	75
97	93	90	87	83	80	77	73	70
92	88	85	82	78	75	72	68	65
87	83	80	77	73	70	67	63	60
82	78	75	72	68	65	62	58	55
77	73	70	67	63	60	57	53	50
72	68	65	62	58	55	52	48	45
1.167	1.163	1.160	1.157	1.153	1.150	1.147	1.143	1.140

scale might be of increased value for taking the individual cell and cadmium readings. Voltmeters are delicate and will not stand abuse with impunity. Care should be exercised not to apply the 0—3 volt terminals to the 110-volt circuit or over more than one cell, as the instrument would very probably be burned out. Also the needle should not be sent in the wrong direction as the violent shock would be liable to bend it out of shape.

Voltage readings of the cells are of value only when taken, while current is passing through the cells either in charging or discharging. They then serve to indicate the condition of the cell under all its states of health.

The leads or small rubber covered copper wires from the voltmeter terminals to the points across which the voltage is to be measured should be of sufficient length to reach from the terminals of the meter to the cell at the most remote corner of the battery, so that readings of every cell may be quickly obtained. A very convenient method of making good contact rapidly between the leads and the cell terminals is to fasten the leads to sharp metal points held in wooden handles. These may be easily constructed by inserting a wire nail into a wooden handle and soldering the lead to the nail. These are familiarly known as "stickers" or "stabbers." One should be conspicuously marked positive (+) or the wire from it knotted at both its ends in order that the positive lead may be placed

upon the positive pole and not on the negative by accident.

The curves in (Fig. 16) are characteristic curves of charge and discharge of a cell and while variation from these will be noted in any particular number of cells under observation, the readings and shape of the curve for any cell will be similar. The age of the plates, temperature and specific gravity of the electrolyte will cause variations in the voltage of the cell, but they will be slight and should not change considerably from time to time for a given cell.

During charge, voltage of a cell will rise from 2.2 volts to 2.5—2.6 volts and during discharge will decrease from 2.1 to 1.7 volts. The discharge should not be carried below 1.7 volts per cell as the voltage drops very rapidly after that point and an abnormal amount of charging would be required to bring the cell back into condition when thus over-discharged. However, should the rate of discharge be higher than the normal or catalogue discharge rate, then the limiting voltage will decrease with increase of current and a somewhat lower voltage is permissible. This is the condition which obtains when cells are discharged under service conditions. When they are being tested, the catalogue rates of discharge should be maintained in order that a definite basis for comparison may be secured. The manufacturers' catalogue discharge rate is a 4, 4½, 5 or 6 hour discharge rate, depending upon the type and thickness of the plates.

By a study of the voltage readings of each cell

of the battery during the progress of the charge, it is possible to determine accurately how the cells are reaching their state of completely charged condition and whether all increase uniformly.

In a similar manner half-hourly readings taken during the discharge show the relative capacities of the cells. Those which give noticeably lower voltages than the rest during the discharge are called "low cells," and if extra charging does not restore them to the condition of the other cells then it is necessary to treat them as explained under "Lack of Capacity" (page 93).

CADMIUM READINGS

The individual cell voltage readings show the variations of potential between the positive and negative plates. Very often it is necessary to know not only that a cell is low in capacity, but which plate is low and for this determination a neutral electrode is used. Cadmium is used for this purpose. It is a metal suitable for this purpose as it contaminates the solution but very slightly. Its use should be confined to the testing of batteries when old, or for cells consistently low in capacity to determine whether the positive or negative plates cause the defect. Other than this, experience has shown it to be preferable to omit the use of the cadmium stick, so that the contamination, which is accumulative, may not be carried to an undesirable degree. A stick about six inches long and of about the thickness of a lead pencil is used, covered with perforated hard rubber, so that contact may be had

with the electrolyte but not with the plates. To the upper end of the cadmium a small rubber covered stranded copper wire should be soldered, the other

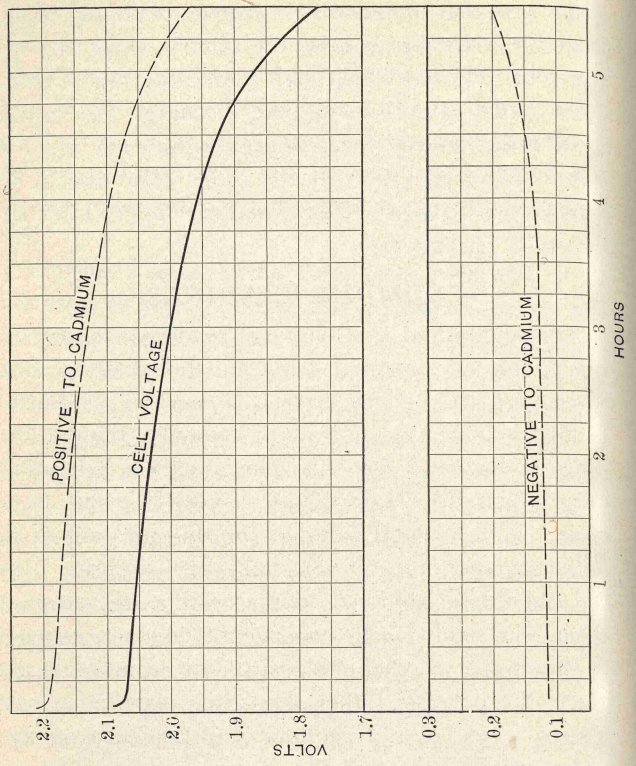


Fig. 16A—Voltage Curves, Showing Cadmium Readings.

end of the wire being connected to the Negative Pole of the voltmeter and long enough to allow the insertion into the electrolyte of any cell of the bat-

tery. To the Positive Pole of the voltmeter is connected the regular lead and stabber.

After the voltage readings have been taken in the regular order, the insulated cadmium should be inserted in the first cell, not allowing it to touch either plate. Apply the stabber from the positive pole of the voltmeter to the positive terminal of the cell obtaining the reading, "positive-cadmium." The difference between the cell voltage and this reading

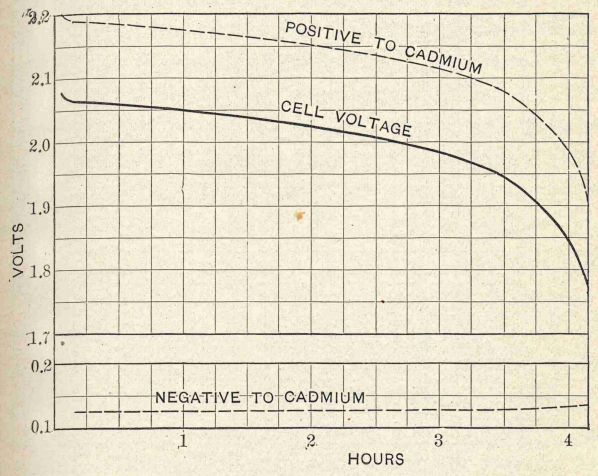


Fig. 16B—Curves Illustrating Discharge in which Positive Plates are Low in Capacity.

is approximately the "negative-cadmium"" reading. Thus when fully charged, the cell voltage being 2.6—2.7 volts, the "positive-cadmium" reading will be 2.4—2.5 volts and the "negative-cadmium" .18—.20 volts. (The variations are due to rate, temperature, age of plates, etc.) In the dis-

charged condition the readings will be approximately 1.7, 1.95 and .25 volts respectively.

At the beginning of charge the cadmium is negative to the negative plate, but as the charging pro-

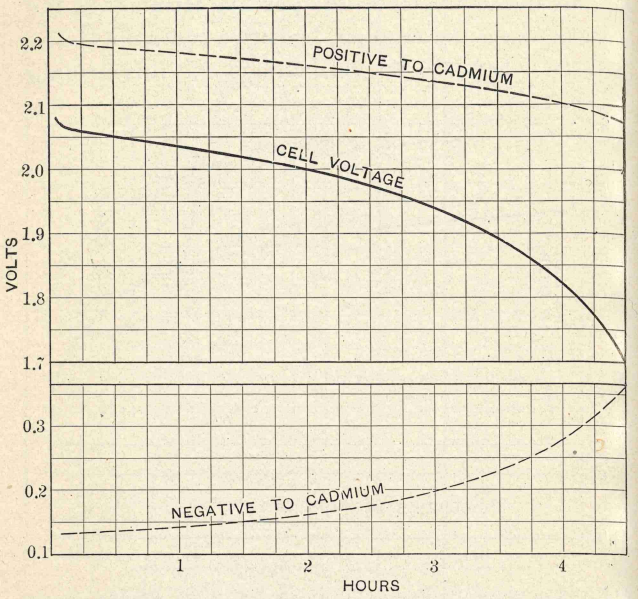


Fig. 16C—Curves Illustrating Discharge in which Negative Plates are Low in Capacity.

gresses this difference decreases and changes direction so that by the time the cell is fully charged the cadmium is positive to the negative plate and negative to the positive plate. During discharge the cad-

nium is negative to the negative plates, the voltage, "negative-cadmium" being in the same direction as "positive-cadmium" voltage, explaining why the "positive-cadmium" voltage is greater than the cell voltage during discharge.

By a glance at curve (a) on (Fig. 16), indicating these results during charge and discharge, it will be noticed that the "positive-cadmium" voltage decreases at the same rate as the cell voltage and that the "negative-cadmium" reading increases slowly at first, but at the end in about the same proportion as the others decrease. This curve is for a typical cell in good condition and comparison with curve (b) of a cell in which the positive plates are deficient will show the importance of these readings. When the rise of "positive-cadmium" voltage in the cell is gradual and the rise in the negative voltage slow, then a healthy condition is assured, but when the "positive-cadmium" readings suddenly decrease in value, deficiency in the positive plates is shown, that is, their capacity is below the normal value. Should the negative plates be affected in this respect, lacking capacity, then the "negative-cadmium" voltage will rise comparatively rapidly and result in a corresponding rapid decrease in cell voltage, curve (c).

SEDIMENT

As explained in the description of storage batteries used in vehicle service, the "Pasted Type" plate is used in practically all cases. Throughout the life of the plates, the active material is slowly

disintegrated and forced off the plate surface, gradually finding its way to the sediment space in the bottom of the jar. Practically, there are two limits to the allowable amount of sediment. When the plate has lost sufficient active material to reduce its capacity abnormally then it is more economical to install new plates than to operate with the old. If the space at the bottom of the jar should not be sfficient to accommodate the total amount of sediment forced off the plates before this condition, then it will be necessary to dismantle the cells and remove the sediment in order to prevent short-circuiting of the plates by the waste material. The proper adjustment of these two limitations is taken care of in design, by the proportioning of the cells, but as space is not sufficient in the electric vehicle to allow larger size jars than are absolutely necessary, it is found more practicable to remove the sediment from the cells at intervals. This is not true in all cases as there is a strong tendency at this time to assemble medium thin or thin plates in high bridge jars so that no cleaning is required during the life of the positive plates. The positive plates are those which are deteriorated most rapidly inasmuch as the active material of the positive plate is very much less coherent than the active material of the negative plate. Hitherto it has been considered good practice to subject a set of positive plates to one cleaning during their life and using one set of negative plates with two sets of positives. As mentioned above, however, the introduction of thinner plates and special types of positive plates has developed the design of a negative plate of life of approximately that of the positive plates with which it is to operate.

By these means, under certain conditions of service where these types of plates are recommended, cleaning is avoided. The process is given in detail, as it is standard practice to remove the sediment from the cells except in the cases mentioned.

The length of time for which a battery would operate without necessitating cleaning, depends upon all the peculiarities of the service and cannot be predetermined accurately, in fact, that is not necessary. The better the treatment and handling that the battery receives, the less frequent will be the removal of sediment. Increasing quantities of sediment make themselves known by decreasing capacity, the more conspicuously by the gradual decrease in specific gravity taken when fully charged. This material resting at the bottom absorbs the sulphate of the acid, decreasing its density so that ordinarily when the density has fallen below 1.250, over the cells of a fully charged battery, it may safely be assumed that the cause is due to the collection of sediment, provided that water has not been added to compensate for solution spilled or slopped from the jars.

After 50 to 75 discharges, one cell of the number should be cut out, the depth of sediment recorded, and replaced. In doing this, the element should be removed without disturbing the separators and without shaking up the sediment while pouring out the acid. Should only a small quantity of sediment

be found, then the cell should be washed out, the element replaced, solution returned and the cell burned into position. An estimate of the growth of sediment may be formed from this, as to the length of time necessary before cleaning, when the sediment has reached to a height of ¼" below the bottom of the plates. Checks may be made upon the rising of the sediment level by removing other cells at intervals for inspection.

When sufficient material has accumulated to reach to within ¼" below the plates, then the battery should be given an overcharge and the cells disconnected.

Where "L" or "T" straps are used, a hack-saw is most convenient for cutting the cells apart. If they are assembled with pillar straps, then a ⅝" drill, in a carpenter's brace, can be used to bore down to the depth of the strap allowing the connector to be easily removed. If they are handled carefully in this manner they may be readily burned, in reassembling without renewal. Care should be given in the use of tools, so that the rubber jars or covers are not damaged. If the cells have been sealed, the sealing compound may be readily removed by means of a hot putty knife.

If the battery is to be cleaned and immediately reassembled, then one cell should be handled at a time, otherwise if the battery is to be left out of commission then the treatment need not be limited to a single cell. The element should be lifted from the cell carefully and placed horizontally on a clean bench, the plates resting on their edges.

Spreading the plates gently, the hard rubber and wood separators should be removed and the groups separated. If the wood separators are not in very good condition, they should be discarded and new ones used in reassembling. But if they are in good condition, then they must be kept wet either by being frequently sprinkled with water or immersed in a vessel of pure water or electrolyte after being washed. The positive group should be rinsed very carefully so that loose sediment may be washed off but no damage done to the plate by a strong stream.

The negative plates should also be rinsed carefully and if the active material has expanded appreciably pressed back into place. This operation is accomplished by inserting clean pieces of wood between the plates of the negative group. The thickness of these strips should be approximately equal to the thickness of positive plate with wood and rubber separators so that the joints of lugs and straps may not be strained. The group may then be placed in the press and the spongy lead forced back into position.

The spongy lead, when exposed to the air will quickly absorb oxygen and be oxidated with considerable heating. The oxidation may be removed by long charging, but it is not well to allow the plates to heat excessively, so they should be sprinkled with pure water in order to prevent it and reassembled, placed in the jar and the acid added as soon as possible. The positive plates will not heat in the air and need no such attention.

Having thoroughly washed the jars, the element,

assembled as in the case of a new battery, is placed carefully in the jar and the solution added without delay. Particular care should be taken to see that the assembly is correct in all details as explained on (page 52). If the old separators have been used, then the jars should be filled with electrolyte of the same specific gravity as that previously in the cell. If, however, new wood separators have been used, then the acid should be 40 points (.040) higher than when the cell was dismantled, in order to compensate for the water in the new separators. After replacing the separator holddowns and hard rubber covers, the cells may be placed in the trays and after going over the assembly with a low reading voltmeter to determine the correct polarities, burned together. The trays and connections should be thoroughly cleaned before the cells are returned to positon. A weak alkaline solution, such as bicarbonate of soda (baking soda), in water, may be used for this purpose after which the trays, when dry, should be given a treatment of acid proof paint. Inspection should be made to see that all connections are correct and secure.

The battery should be given a charge at the finishing rate (pages 28-37), and continued until the voltage and specific gravity of each cell has ceased to rise for a period of ten (10) hours.

It is recommended that a test discharge be made before placing in service so that the condition of each cell may be found correct. The capacity will be slightly less after cleaning than before, but will increase as the battery is worked.

DIFFICULTIES AND THEIR EVASION

Of the different parts of the electric vehicle, the storage battery is the most important and while responsible for some deficiencies is not open to criticism for everything that goes wrong with the vehicle. A general tendency has been to find that there is something wrong and then assume without question that it is the battery. Besides being unjust, such an assumption is not always founded on fact.

The battery is rated in ampere hours and not in miles so that if the roads be heavy due to mud or snow, or if the brakes bind, the ampere draw will be increased and the mileage necessarily reduced. Brakes, motor bearings and connections should be frequently inspected so that the energy consumed in running may be as small as possible. Inefficient tires are very often a source of trouble. Such tires may consume more current in locomotion than all the elements of vehicle and load put together.

However, should the vehicle with the exception of the battery be found in good order, then it is reasonable to look there for the trouble. The most common difficulties encountered in the operation of lead storage batteries in vehicle service are the following:

1. **Loss of Capacity.** Loss of capacity of the battery may be occasioned by avoidable or unavoidable causes. The unavoidable causes are accident and the natural wear and tear incident to its operation in rigorous service, presuming the correct care. The avoidable causes are lack of care either in hand-

ling the battery in the garage or in operating the vehicle on the highways. This includes allowing to stand in a discharged condition, failure to repair as soon as possible after the development of a leaky jar or internal short circuit, failure to remove sediment before reaching the bottom of the plates and allowing impurities such as iron, chlorine, copper, and organic matter to find their way into the electrolyte. The specific reasons for loss of capacity and their remedies are given under 2, 3, 4, etc., as they all affect the capacity or output of the battery.

2. **Sulphation.** Sulphation, or the presence of lead sulphate in the active material of the plate in hardened form, not reduced by usual charging is produced by allowing the battery to stand in a discharged condition. It stands to reason that if the battery is given the small amount of necessary care as required, then sulphation can only be due to accidental cause, which is either avoidable or unavoidable. Assuming that with the slight education necessary that only the unavoidable will remain, there should be very little possibility of damage from this cause. The remedy should be immediate and thorough as the effects are additive. A thorough overcharge at a low rate followed by several cycles of charge and discharge will usually be sufficient to bring the battery back into good condition.

3. **Reversal of the Plates.** This is a difficulty which arises only in rare instances but might occur when the cell loses capacity and during the discharge its capacity is exhausted before that of the other cells, resulting in current being forced through it,

reversing its plates. Under usual conditions this is not a very probable difficulty providing that a regular inspection of voltage and gravity are made, but, should it be found, then the treatment described for Sulphation (No. 2), will usually bring the cell back into condition.

4. **Shedding of Active Material.** It is obvious that the plates of the storage battery are made to give the maximum life with the maximum capacity during that life, but it is only reasonable to allow that they wear out. In this respect they are almost human and during the life of the plates the capacity gradually decreases until finally it is more economical to scrap them and install new. This is an unavoidable cause and can be tempered only by giving the little attention necessary at the correct time. The main cause of shedding or loss of the particles of active material is excessive gassing. The action involved has been explained on page (4). The loss of the minute quantities from the plate under the violent gassing shortens the life of the plate. This is probably the most important difficulty and the remedy consists only in prevention which is simplicity itself. Permit only moderate gassing at all times.

5. **Corrosion of Plates.** As the battery in whole or part is furnished by the manufacturer it is chemically pure so far as harmful impurities are concerned and if distilled water and chemically pure sulphuric acid alone be used during the useful life there need be no cause for trouble. However, should impurities such as copper, iron, mercury,

chlorine, nitric acid, platinum, organic matter, etc., be introduced the passage of current will cause them to react upon or corrode the active material of the plates. Necessarily this will reduce the capacity of the cells as it will reduce the amount of active material effective in useful chemical reaction. The remedy consists in removing the corrosive agent. This is described under "Electrolyte," page (73).

6. **Temperature.** At high temperatures chemical action takes place more vigorously and physical effects are more pronounced. Thus the action of hot acid upon the plates and separators is unnecessarily severe for the service rendered, resulting in reduced life. The physical effect of the heat upon the rubber jars is to warp them. It is a simple matter under all usual conditions to keep the cell temperature well below 110° F., but should it reach this limit on charge then the current should be interrupted until normal temperature has been attained.

Extremely low temperatures will cause a temporary decrease in capacity. Bringing the battery to its normal operating condition, however, will make the total capacity available. Only in the most unusual instances are difficulties of this nature experienced. Acid of 1.130 specific gravity will freeze at 0° F., but 1.275 acid will not freeze at 40° below zero.

TAKING OUT OF COMMISSION.

Under certain conditions of service the battery may be allowed to stand for days or perhaps weeks at a time without being discharged, in which case

it is necessary only to maintain the proper level of ½" above the plates for the electrolyte by the addition of pure water and to keep in a charged condition. Ordinarily it is not necessary to charge unless over 50% of the capacity has been discharged, but if the battery is to stand idle for weeks it should be fully charged, and in the case of the battery which is to remain idle for several months, it should at least be given an overcharge before and immediately after the period of idleness. The best practice is to give an overcharge once in two weeks and not less in any case than once a month. Where the battery is to stand without use for over four months or facilities are not available for giving the periodic overcharge required, then it is best to take the battery apart for dry storage. Furthermore, if the battery has been used considerably and is about ready for the removal of sediment, then both purposes can be served at the same time by taking apart and cleaning, leaving the battery ready for assembly when needed. The length of time during which a battery may stand in dry storage is very long, as practically no changes take place if the plates have been treated properly.

The battery should be given an overcharge and dismantled as explained under "Sediment," page (87). The positive plates should be rinsed to remove any loose material and allowed to dry when they are ready for storage. In most cases it will be found more practicable to discard the wooden separators. The perforated hard rubber separators, however, may be washed thoroughly and if not

damaged, saved for future use. The acid may be carefully poured into a clean carboy and saved. The jars, hold-downs, connectors, etc., unless damaged should also be very thoroughly cleaned and stored.

After separating the groups from the element, the negative plates may be dipped in pure water and pressed if necessary after which they should be allowed to soak in 1.275 acid for three to four hours, then removed and dried.

As explained under "Sediment," the negatives will heat to a certain extent while drying and this should be kept a minimum by sufficient sprinkling of pure water. The evaporation of the water will absorb the heat from the plates and allow them to dry comparatively quickly without danger, after which they may be put in storage for an indefinite period.

The parts should be placed in a dry and clean place and protected from dirt, dampness, etc.

The directions for putting the battery into service are identical with those given for assembling and placing in commission of new batteries. In this case, however, the plate lugs remain burned to the straps and unless damaged in handling need no burning as do the plates received separately when new.

BATTERY ACCESSORY SUGGESTIONS

Hydrometer syringe.

Double scale portable voltmeter for locating low cells, discharges, etc.

Earthenware pitcher, two-quart.

Earthenware crock, 5-10 gallons, for mixing acid.

Distilled water for flushing.

Carboy of 1.300 electrolyte.

Moderately heavy mineral grease for greasing brass terminals.

Wire jumpers with suitable terminals for connecting trays when charging outside of the vehicle.

Extra jars and covers.

Bench or platform truck to hold battery when outside of vehicle.

Rubber gloves.

Thermometer.

Bicarbonate of soda.

LEAD BURNING—MANIPULATION OF HYDROGEN GENERATORS

In the preceding pages frequent mention is made of the method of connecting the plates into groups and the groups of one cell to those of the next by means of "lead burning" the connection. Lead burning, as explained on page 25, consists in applying a flame of sufficient heat to the cleaned lead parts to make them melt and flow together. In this operation solder is not used but pure lead in stick or bar form, for convenience in handling, is used to supply the filling. This requires very little elucidation as it can be readily seen that the lead joint is very easily made since this metal has a very low melting point and it is not oxidized freely at ordinary temperatures.

The flame which is used to melt the metal at the point of application is known as a hydrogen flame and is concentrated and non-oxidizing and is secured in a relatively simple manner, namely by the action of sulphuric acid upon zinc. The acid attacks the zinc and produces hydrogen gas which is conducted through a bottle of water "O" (Fig. 17) to wash out and remove acid spray or zinc dust, as well as to prevent the flame being drawn back into the generator causing an explosion. The gas, conducted to the Burner's Tee is mixed with air at a slight pressure, forcing it out of the burning tip with a small hot flame.

The complete outfit necessary for lead burning consists of the following parts:

One hydrogen gas generator.

One bottle or trap (for cleaning the gas and preventing the flame from drawing back into the generator).

One air pump.

One air tank.

One lead burner's mixing tee.

One length of 150′ of 5/16″ soft rubber tubing (cut into lengths as per requirements).

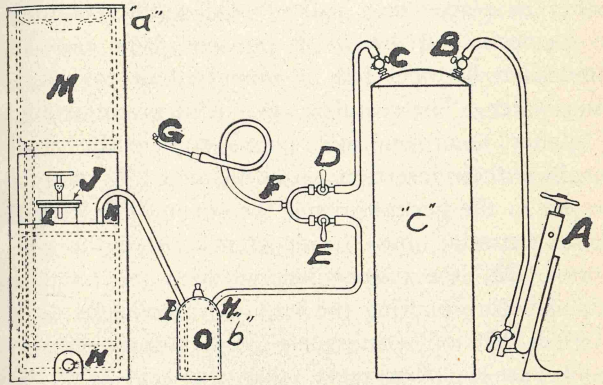


Fig. 17—Hydrogen Gas Outfit.

One blowpipe.

Set of tips for burning.

The size of the generator will depend upon the number of flames to be furnished from it. Size No. 1 is generally used when but one flame is to be operated, while size No. 2 or larger is used depending upon the number of flames to be furnished.

Operation. When the generator is connected for use, the parts will be arranged as shown in the diagrammatic sketch shown on page 101, in which "a" shows the hydrogen generator, "b" the washing bottle or trap and "c" the air reservoir. The bottle should be filled about two-thirds full with water and connection made to the generator by the tubing "K-I" allowing the tubing to reach to the bottom of the bottle as shown in the drawing "b." Should this bottle become heated, it should either be placed in a pail of cold water, reaching to its neck, and the water replaced from time to time as it becomes hot or immersed in cold running water. The required amount of granular zinc ("spelter"), broken into pieces sufficiently small to allow their insertion at the opening "L" should be put in the generator and the cover "J" clamped down securely. Into the upper portion of the generator "M" the proper amount of water is then added before pouring the required amount of acid, "Oil of Vitriol" (Sulphuric Acid, but not chemically pure). *Remember* that the acid is to be poured into the water and very carefully to prevent splashing out. Should any acid find its way onto the skin, oil should be applied rather than water. The main point is to get it off quickly.

The length of hose from the mixing valves "D" and "E" to "G" should be no longer than necessary for convenient handling so that the gas and air valves "D" and "E" can be within ready reach and easy control of the operator. The air pump "A" is used to create the air pressure in the reservoir so that when the pumping is discontinued the cock "B" is closed until further pumping is necessary. The cock "C" is opened and with that of "D" closed the gas is allowed to escape from the burning tip "G" by opening the cock "E," and is lighted with a match or candle. When the gas is ignited "D" is opened and the flame regulated by closing "E" until the adjustment gives a flame which will melt the lead leaving a clean bright surface. Trial of scrap lead will show a correct adjustment and the flame is then ready for use.

The size of the burning tip used will depend upon the character of work to be done; usually all the lead burning required in vehicle work can be accomplished with the tips with small holes. The adjustment of gas and air will also vary the size and flame to suit almost all conditions.

The apparatus should be set up in such a manner that there is no possibility of water discharging over into the tube between "H" and "E" as it is evident that this would discontinue the flame and add dirty water either onto the straps or bars or into the cells. Should water be formed by condensation in this length of tubing, however, it may be removed by kinking the hose between "K" and "I," detaching the tubing at "H" and allowing the pressure in the air tank to force the water out by opening the cocks "E," "D," and "C."

The amounts of zinc given in the table are usually sufficient for three renewals of water and acid so that when the charge is exhausted or the operation is discontinued for a night or any period, the

solution should be drawn off and the generator flushed out with water poured into the upper chamber. The new acid should not be added until it is to be used. Before discharging the solution from the generator, the tubing at "H" and "K" should be removed before taking out the rubber plug at "N." As this acid solution is corrosive, it should not be allowed to come in contact with anything near to it or be thrown where it may have opportunity to damage the boarding, asphalt, cement, etc. When discharged into the plumbing, the latter should be well flushed immediately in order to prevent any action upon the piping or fittings.

Its action upon most substances can be counteracted by the quick application of alkaline substances such as ammonia, washing soda and the commercial cleaning compounds ("Gold Dust," "Dutch Cleanser," "Pearline," etc.).

MATERIAL REQUIRED IN STARTING UP A GENERATOR

Size of Generator		Zinc	Water	Vitriol
No. 1	15″ x 15″	20 lbs.	9 gals.	2 gals.
No. 2	18″ x 18″	25 lbs.	12 gals.	3 gals.

If the work does not demand the quantity of hydrogen generated in this apparatus then tanks of hydrogen and oxygen or compressed air may be purchased and readily connected to the mixing tee. If there is available a supply of air under pressure, then the tank of compressed air may be dis-

pensed with. It will probably be necessary to use a reducing valve as two (2) pounds pressure per square inch is usually sufficient for the purpose. Figures No. 12 and 13 show the burning box and burning rack used in burning the plates into the straps.

A device for accomplishing the results given by the hydrogen flame is shown in (Fig. 18) and consists of a clamp with insulated wire attached to a carbon electrode mounted on an insulated handle.

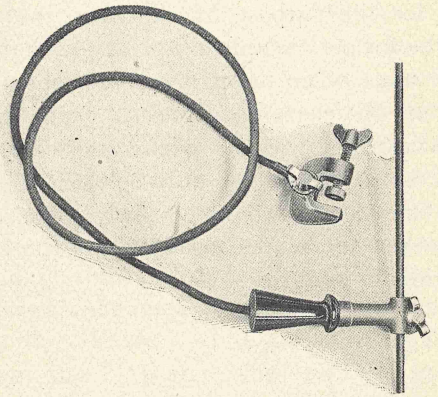


Fig. 18—Arc Lead Burning Outfit.

The clamp is attached to the connecting strap of a cell near the one upon which the burning is to be done. In this manner by connecting across 5 cells, a potential of ten volts is available for the arc. The connections should be made so that the carbon is the negative pole. The latter is then touched to the lead, striking an arc with the strap and pro-

ducing a concentrated flame over the section to be lead burned. The materials used in this case are identical with those used in the operation of the hydrogen flame excepting that the heat is produced by the arc instead of the hydrogen generator. In work involving the use of an arc it is always well to wear blue glasses to protect the eyes.

Where neither of these methods are available for mending connections, as for instance, the breaking of a connector upon the road, a soldered joint may be made for temporary use. This, however, is only for the purpose of reaching the garage where the proper treatment can be given.

At all times when the parts of the cells are lead burned or the elements connected, care must be given that strips of lead or pieces of solder do not gain access to the cell or flow between the plates as this "flowdown" would be likely to make contact between the plates, contaminate the electrolyte or do other damage.

CHAPTER IV.

COMMERCIAL TYPES OF LEAD STORAGE BATTERIES

(Arranged alphabetically)

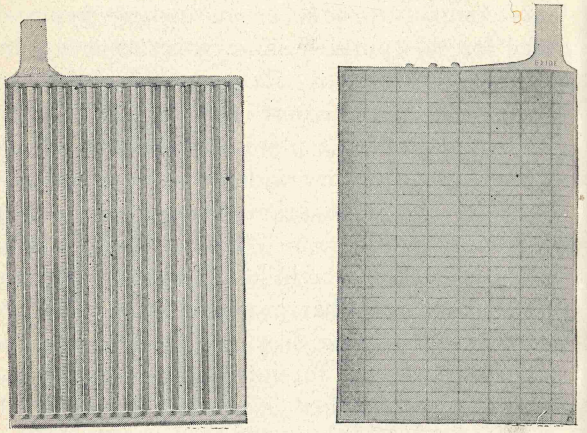
Electric Storage Battery Company, Philadelphia, Pa., "Exide"

This company produces four distinct types of battery for this purpose, known respectively under the trade-names of "Exide," "Hycap-Exide," "Thin-Exide" and "Iron-Clad-Exide."

The standard Exide plate was the first of the four and is still in very wide use throughout the country, giving satisfaction where it is used in the proper application. The "Hycap-Exide" plate is of the same size in length and breadth but is not as thick, so that more plates may be assembled in the same size jar as used for the "Exide" plate and is intended for use where the daily mileage consumed is greater than that afforded by the "Exide." The daily mileage procured from the "Hycap-Exide" will be greater than that from the "Exide" but the total mileage under average conditions will be approximately the same. The type of grid used in these plates, shown in (Fig. 8, p. 22) is known as the "staggered bar type" and serves as a very effective container for the active material which receives special treatment, the result of many years of experimenting.

The "Exide" and "Hycap-Exide" type plates

are each made in two sizes known as "MV" and "PV." The length and thickness of the "PV" plate is identical with that of the "MV" plate, of the corresponding type, but the width is reduced from 5¾" to 4 13/16" or a reduction of about 16%. The "PV" type plate is used where the output required is somewhat less than that required from the "MV" type plate.



POSITIVE. NEGATIVE.

Fig. 19—"Iron-Clad-Exide" Plates.

The "Thin-Exide" plate has the same general dimensions in length and width as the preceding types but being thinner the manufacturers state that even greater mileage may be secured upon a single charge of the battery than from the "Hycap-Exide" plate. The total mileage, however, during the life of the plates as compared with either the "Hycap-Exide" or "Exide" plates should be about the same. The statement is

also made that where the daily mileage given by either the "Hycap-Exide" or "Thin-Exide" plates is not required, the "Exide" should be used and will be found more satisfactory from the standpoint of service and economy.

Within the past few years this Company has introduced and placed large quantities of cells in service equipped with a positive plate known as an "Iron-Clad-Exide."

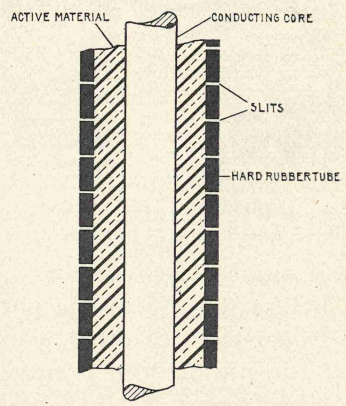


Fig. 20A—"Iron-Clad-Exide" Tube.

This plate known also as the "Pencil Positive" Plate is shown in (Fig. 19). The manufacturers find that in this plate greater effective surface is secured for the active material, giving greater capacity than the "Exide" plate and that by this design a life of two or three times that of the "Exide" is obtained.

The active material is held in the rubber (Fig. 20) in such a manner that ordinary wear and tear will not dislodge it with the same rapidity that will obtain in the "Exide" so that the accumulation of sediment will be very much less rapid and the useful life of the plates will have been secured before it is necessary to take the cells apart for cleaning. The negative plate has the same characteristics as those found in the "Exide" cell but in this case is made slightly heavier in order to compensate for the increased

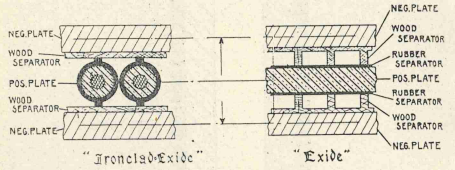


Fig. 20B—Cross-section of "Iron-Clad-Exide" Plates.

life of the positive plates without necessitating a renewal before the life of the positive plates have been exhausted. In other words, it is intended that the life of both positive and negative plates shall be equal. In the assembly of the plates a perforated hard rubber sheet separator is not required. A thin wood separator especially treated and cross grained is used, however.

A flexible connection shown in connection with the description of the cell is another feature characteristic of the "Iron-Clad" assembly. Frequent reference has been made to the disconnecting of cells in the preceding pages and the method

given, that of drilling through the strap to the pillar post.

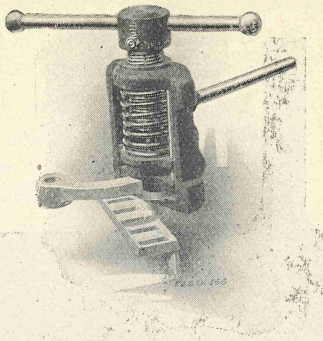


Fig. 21—Connector Puller as Applied.

A connector puller produced by this Company is designed to accomplish this result in a simple and effective manner. It is placed around the connection as shown in (Fig. 21) and shears the connector free from the post without injury to either, so that the connector may be again used.

Gould Storage Battery Company, New York City

The plates produced by this Company use the staggered bar grid which has been found very satisfactory and efficient in vehicle battery practice. Numerous experiments and years of service have proven this statement a fact. The claim is made by the manufacturers that the active material in the positive plates is compounded in a manner designed by a special process for hard-

ening without entailing loss in capacity, the principle being the use in service of a layer of active

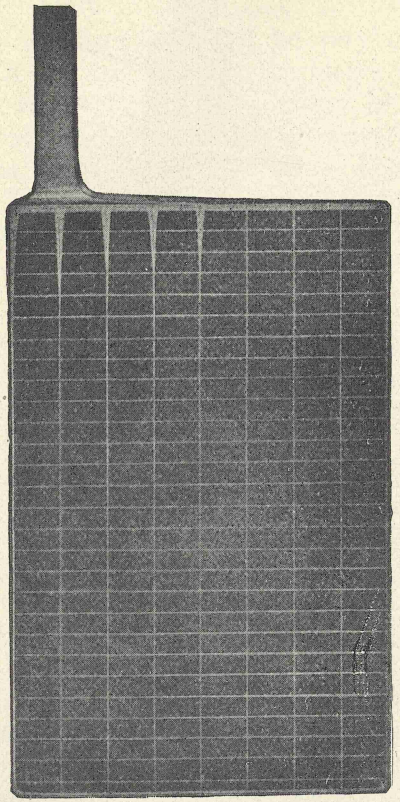


Fig. 22—Gould Type "TH" Positive Plate.

material of sufficient thickness to give the necessary capacity but not thick enough to increase the precipitation of sediment (Fig. 22). Practically, this works out well for, as the active material falls off through wear, the hard material in the center is softened at approximately the same rate, and thus maintains a uniformly thick layer of active material and uniform capacity during the life of the plate.

From the above it will be seen that great effort has been expended in the many details involved in producing plates of such a character that the all important features of resistance to wear, retention of capacity and ability to withstand severe service conditions, such as dislodging of active material through overcharge or damage due to jarring, may be secured. The negative plates are constructed with the same ideas in mind, and an effort is made to prevent shrinkage and softening of the material, which would result in its rapid loss.

The plates decrease in thickness through seven types so that the proper size, type and thickness of plate is available for each class of vehicle service. The so-called "thick" or "standard" type plate is designated by this Company as type RP, and the medium "Hycap" as MC. The TH and THS are the thin plate types. Types NR, NM and NH are the corresponding designations for the thick, medium and thin plates in the narrower style of plate. These types include the medium, thin and high capacity thin plates as shown in the accompanying tables.

In the higher capacity types this Company claims to have succeeded in developing combi-

nations which will give increased total mileage life in direct proportion to the increased mileage per discharge; that is, the total number of discharges is the same for the higher capacity type as for the "standard" or "thick" plate, so that increased mileage per discharge results in increased total mileage life. They claim this is particularly true in their type MC.

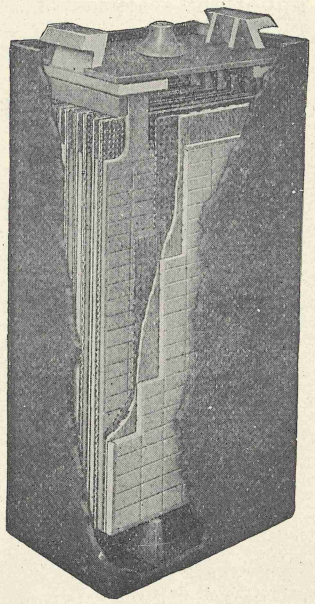


Fig. 23—Gould Type "TH" Cell.

The detail construction of batteries and their plate combinations are designed to meet the generally accepted standards of vehicle manufac-

turers as regards number of plates per jar, size of jar, medium or high bridges, different forms of connections between cells, battery accessories, etc., as shown in Figure 23.

Philadelphia Storage Battery Company

This Company has developed a very successful type of plate which receives its name from the

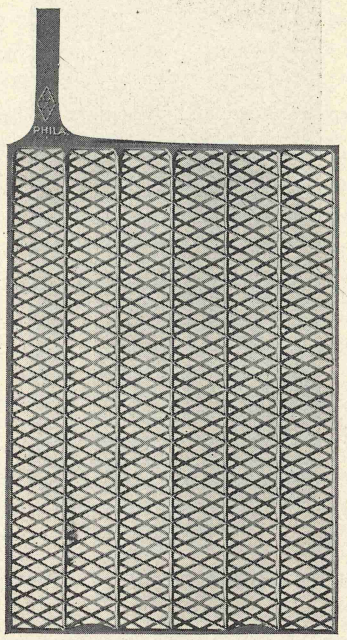


Fig. 24—The Philadelphia "Diamond" Grid.

construction of the frame, the "Diamond Grid." Figure 24 shows a skeleton obtained by placing

two sheets of diagonal lead net opposite each other and allowing space between for the active material so that when the compound is finally pressed into place the plate is given a smooth surface with the active material confined within

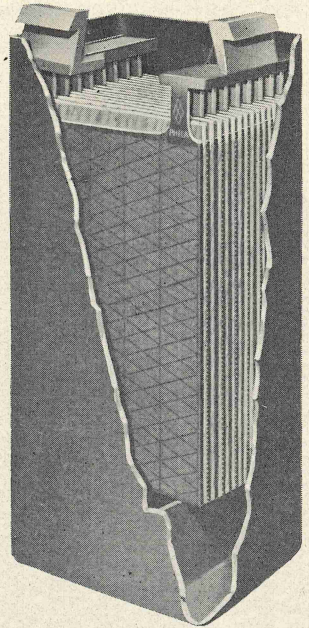


Fig. 25—Philadelphia Cell, Type "WTX."

the staggered meshes. These staggered diagonal members are designed to give strength for resisting a buckling or warping action and is a firm support for the active material so that hard

service may be endured through a considerable life.

The Philadelphia plates are made in the thick, medium, thin and extra thin types with sizes of each type varying slightly according to the service application in order that the minimum weight with the maximum life and capacity may be secured. The most prominent of these is known as the "WTX" or "Diamond X" (Fig. 25), an extra high capacity thin plate which represents an increase of approximately 54.5% in capacity over the Standard thick plate, type "W." The positive and negative plates are so designed and the space for sediment increased with extra high ribs (2¾") that no renewal or cleaning is necessary during the useful life of the battery. This type of plate is recommended by the makers for the majority of vehicle battery equipments because of its light weight and the extent to which the chemical actions penetrate its body.

United States Light and Heating Co., N. Y. C., "USL"

A glance at the illustration in (Fig. 26) will serve to show the method of construction of the staggered bar grid used in the manufacture of this plate. The "CB" negative grid shows a variation from that found in the other types. The metal web is perforated so that triangular prongs are raised from the sheet metal of the grid and serve to firmly hold the active material in place. The retention of a maximum amount of active

material considering weight and wear is claimed for this arrangement. The careful methods used in the manufacture of the component parts and

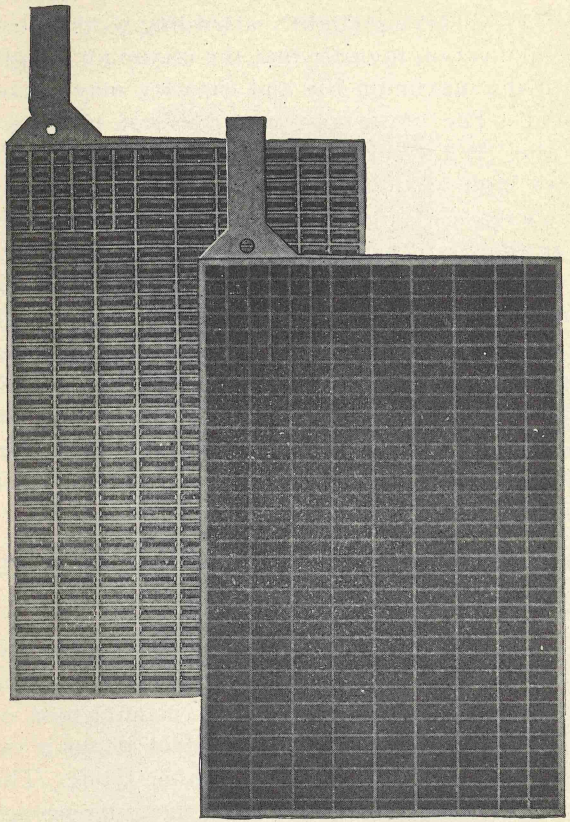


Fig. 26—"USL" Positive Plate and Grid.

finished plates are reflected in the quality of service which results.

The ribs supporting the plates are furnished with soft rubber tops so that the vibration and

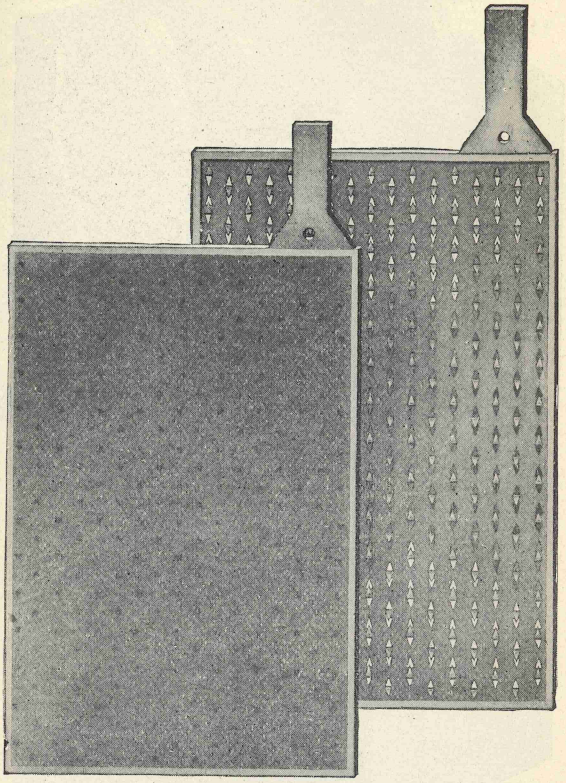


Fig. 27—"USL" Negative Plate and Grid.

jarring from travel over bad roads will be cushioned and reduced, thus eliminating a source of loss of active material.

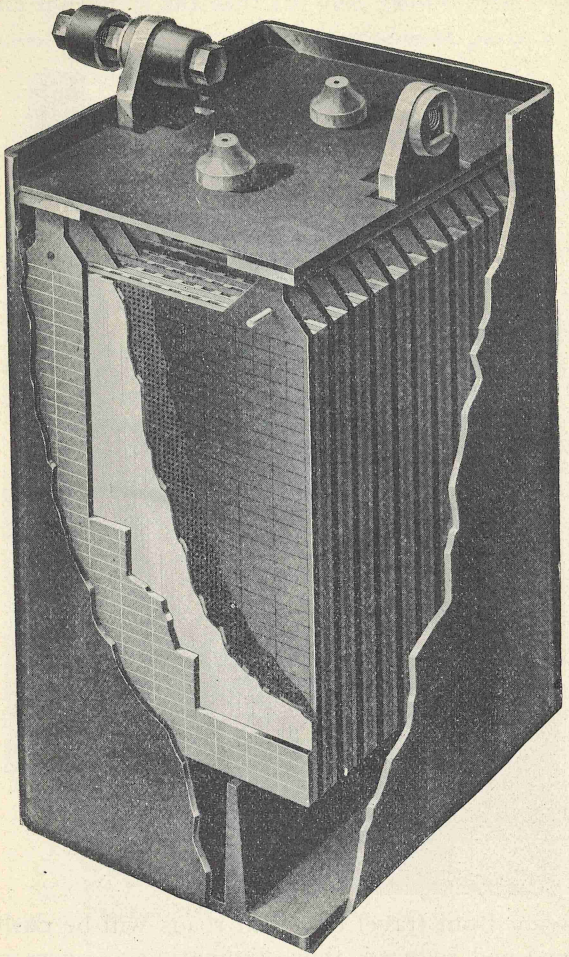


Fig. 28—"USL" T Bolt Strap Cell.

The types of plates include those of the medium and thick design so that the fields of electric vehicle service are covered. The construction of the plates with either "L" or "T" strap or pillar post connectors admits of flexibility in the methods of assembly for either side or end assembling of cells. The bolt connector shown in (Fig. 28) makes a still more flexible arrangement where the latter may be necessary.

Willard Storage Battery Company, Cleveland, Ohio, "LBA"

In the manufacture of the "LBA" type of battery a great deal of attention has been paid to

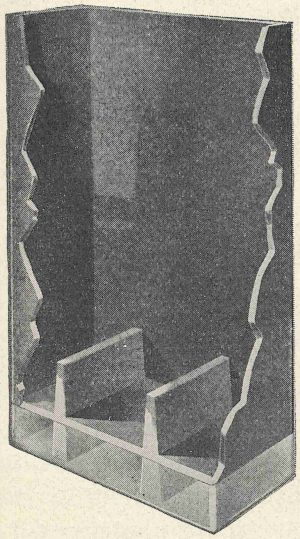


Fig. 29—Jar with High Mud Space.

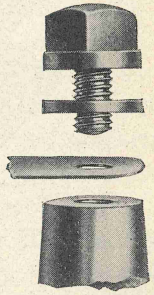


Fig. 30—Pillar Bolted Top Connector.

the perfecting of the numerous details connected with the manipulation of the battery after it is

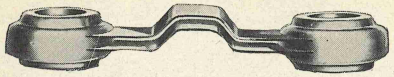


Fig. 31—Copper Plate Top Connector.

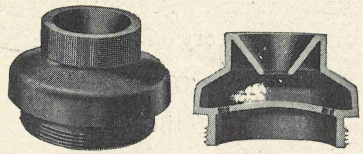


Fig. 32—Vent Plug.

put into the user's hands. These include jars with heavy walls to insure against breakage.

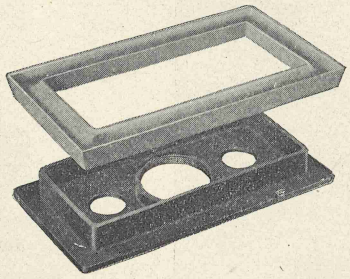


Fig. 33A—Cover with Gasket.

These jars (Fig. 29) are furnished in two depths so that should a deep space be required for the collection of sediment, obviating the necessity of cleaning, the deeper cell may be used. The

connectors are made in either the pillar type burned link or the unbreakable connector formed by using lead plated copper as a connecting medium (Figs. 30 & 31). For use where quick con-

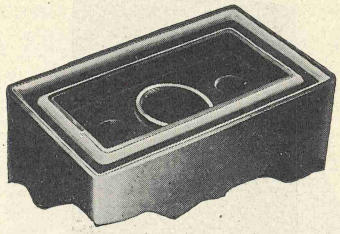


Fig. 33B—Cover in Place.

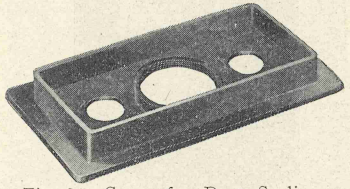


Fig. 34—Cover for Deep Sealing.

necting or disconnecting may be required, the pillar posts are threaded to accommodate the bolted top connector screw which secures the bolted connector into place. In addition to these features, the plates may be assembled with either the "L" strap or "T" strap connectors. A vent plug is furnished as shown in section in (Fig. 32) for the purpose of allowing the gas to escape without carrying electrolyte spray with it.

The plates (Fig. 35) are of the staggered bar grid construction with active material pressed

firmly into place leaving a flat surface and are made in the heavy, medium and thin types. Last-

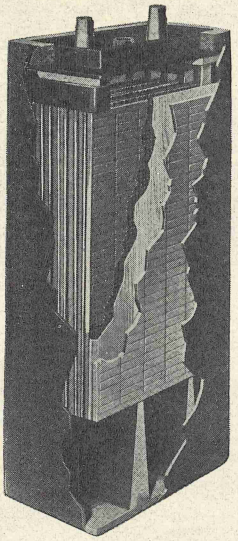


Fig. 35—Willard Cell, Showing Construction.

ly, covers (Fig. 33) are available for these cells which permit quick sealing by the use of a pure soft rubber gasket. This allows the cover to be inserted over the gasket sealing the jar immediately and just as readily removable. Where this is not necessary the cover is furnished so that deep sealing with compound can be accomplished with little trouble by the extra wall shown in the sketch (Fig. 34).

CHAPTER V.

ALKALINE STORAGE BATTERIES (EDISON BATTERY): DESCRIPTION AND CARE

Of this class of cells there is but one combination of elements which has met with practical success. The Edison battery has the same general

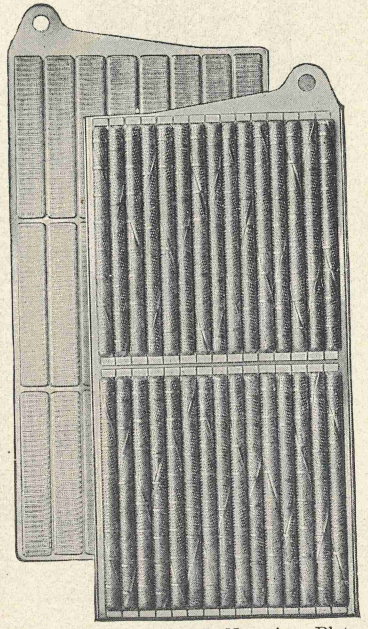


Fig. 36—Positive and Negative Plates.

characteristics as the lead battery but no lead is used in its construction and the electrolyte is a solution of caustic potash instead of sulphuric acid.

The peculiarities of construction and the character of the materials used enable the manufacturers to claim a long term of service for the cells.

Fig. 37A—Positive Tube.

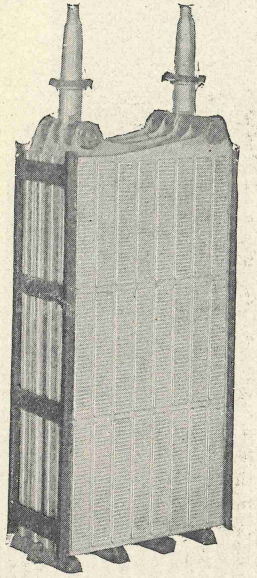


Fig. 39—Type A-4 Cell Assembled, but Removed from Container.

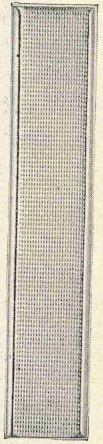


Fig. 38A—Negative Pocket.

The grids for both positive and negative plates are stampings from sheet steel. These, as well as all other steel parts used in the assembled cell are nickel plated to prevent corrosion. The active ma-

terial is contained in tubes or jackets, fastened rigidly to the supporting frame or grid and giving electrical conductivity.

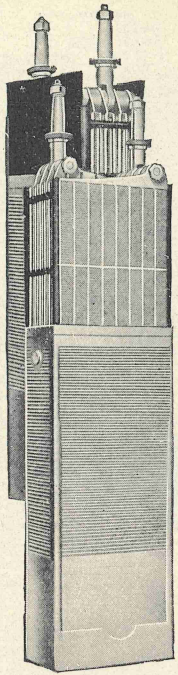


Fig. 40.—Contents of Container Partly Lifted, Showing Alternating Positive and Negative Plates.

The positive plate (Fig. 36) is built of horizontal rows of fifteen (15) vertical cylindrical steel tubes containing the active material nickel hydrate, interspersed in thin layers with pure nickel

in position on the grid and under heavy pressure, forced into close contact with it, at the same time making the surface of the pockets corrugated, thus supplying a firmer contact between the metal and the active material. The type A plate has twenty-four (24) pockets arranged in three horizontal rows.

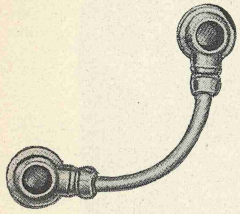


Fig. 43—Cell Connector.

Fig. 44—Flexible Connector.

The plate frames have a hole located in one upper corner through which a steel stud is passed. Two groups (Fig. 39) respectively of positive and negative plates are formed by arranging the required number of plates with spacing washers and a terminal post at the centre of the stud. The end of the studs are threaded and nuts hold the plates and spacing washers rigid. These two groups (positive and negative) of the cell are placed together so that the positive and negatives alternate, there being one more negative than positive plate. Between the plates hard rubber rods are inserted and serve the purpose of insulating and properly spacing. Pieces of hard rubber in ladder form (Fig. 39) are fitted snugly, by grooving, to the edges of the plates so that a well insulated but firm and rigid unit is obtained.

The receptacle used to hold the elements is called, in this case, a can (Fig. 40) as it is made of sheet steel, nickel plated with corrugated sides to furnish strength. The seams on side, top and bottom are welded by the autogenous method with the oxy-acetylene flame. The can receives the insulated unit described above, a hard rubber support (Fig. 39) preventing contact of plates and can at the

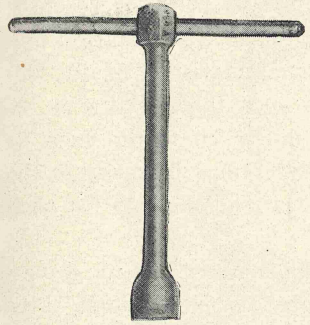


Fig. 45—Socket Wrench.

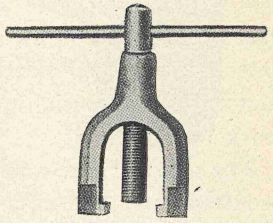


Fig. 46—Disconnecting Jack.

bottom while two thin sheets of hard rubber are inserted between the outside negative plates and the can. The cover (Fig. 41) for this can is provided with two fittings through which the pole pieces pass, being suitably insulated by rubber washers which also prevent passage of gas or liquid. A combination filler and gas vent is placed in the centre of the cover and allows the addition of solution or distilled water to the cell. The

hinged cover of this mounting is designed so that the gases liberated during operation may be discharged without allowing entrance of air or impurities as these would cause contaminated electrolyte reducing the efficiency of the cell.

The welding of this cover into place completes the cell except for the electrolyte, which is a 21% solution of potassium hydrate with a small quantity of lithium hydrate.

The cell is filled with electrolyte until a level of about ½" above the tops of the plates is reached. The cell is then ready for the forming charges and service conditions. The characteristics of the design and manufacture are such that repairs or replacements, except of a minor character such as external parts and electrolyte, must be made at the factory unless special apparatus is at hand for such work.

The cells, of size and number dictated by service requirements, are assembled in hard wood trays (Fig. 42) attached at the tops of metal clamps and at the bottom by metal cradles. The trays permit of easy handling, ready inspection for damage, or quick exchange of cell as well as good ventilation.

The terminal posts or positive and negative poles referred to above are tapered and threaded at the top. The connectors (Fig. 43) are formed by swedging a nickel plated copper rod into two lugs bored so as to fit firmly on the tapered poles. The placing of the connector thus accomplishes the connection of adjacent cells and admits of connection

between trays, parts of the battery, controller, etc. Where connections must be flexible a stranded conductor (Fig. 44) instead of a copper rod is soldered into the lug. Nuts are screwed tightly into position (Fig. 45) making connection firm and

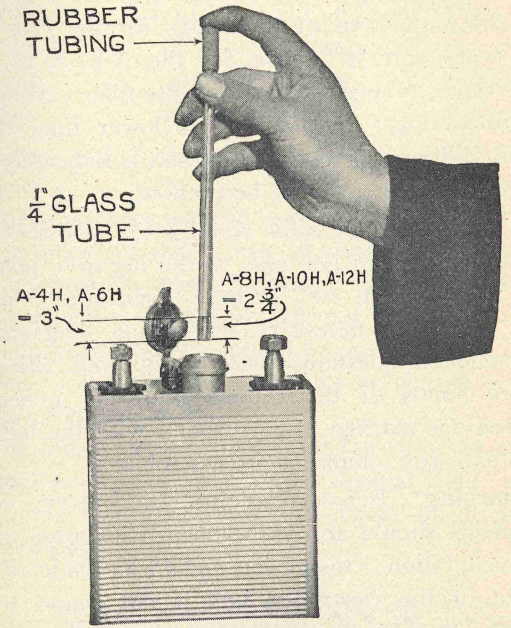


Fig. 47—Quick Method of Determining Level of Electrolyte.

permanent at the same time admitting of quick and easy disconnecting. A disconnecting jack shown (Fig. 46) is used to remove the connector from the poles.

Care and Operation. In addition to the general instructions given above which apply to all storage batteries, the following are applicable to the Edison battery alone.

Upon arrival of the cells inspection should be made of the height of the solution level (Fig. 47) ½" above the tops of the plates for the A-4 and A-6 types and ⅛" above for the A-8, A-10 and A-12 types, taking care to close the filler caps after the inspection. If the level is lower than these values spilling or damage in transit is indicated and the manufacturer should be notified.

In making connections connect the positive pole of the end cell of one tray to the negative pole of that in the next, etc. Where connections other than these are necessary the wiring diagram of the vehicle in question should be followed, although the terminals of the vehicle leads are generally lettered ore marked to correspond with the battery terminals for simplicity in assembling.

Charging. Before charging, the battery compartments should always be opened in order to allow ventilation. Inspection should be made of the height of the electrolyte and if not found to be correct, then it should be brought to the proper level by the addition of distilled water only as described below and added before the charge is begun. (Page 139.)

The charging voltage required for various numbers of cells usually encountered in vehicle practice is in (Table 8) or may be easily calculated by multiplying the number of cells to be charged by 1.85 volts.

TABLE No. 8.

VOLTS REQUIRED TO CHARGE

No. of Cells	Volts Across Cells	No. of Cells	Volts Across Cells
10	18.5	60	111.0
20	37.0	70	130.0
30	55.5	80	148.0
40	74.0	90	167.0
50	92.5	110	185.0

These voltages are the lowest sufficient to charge the numbers of cells given in series, at the normal rate toward the end of charge. While a few per cent. reduction in voltage will not materially affect the charge, allowance should be provided if it is required to charge at higher rates or charge several combinations of cells.

The initial charge should last for 12 hours at the normal rate for service. The "Normal Rate" is the catalogue rate of current for charge or discharge prescribed by the manufactuer.

TABLE 9.

ELECTRICAL DATA

Type of Cell	A-4	A-5	A-6	A-8	A-10	A-12
Capacity, Ampere Hours	150	187.5	225	300	375	450
Normal Charge Rate, Amperes	30	37.5	45	60	75	90
Normal Discharge Rate, Amperes	30	37.5	45	60	75	90

The normal charge for a battery practically discharged is seven hours at the normal rate (Table 9) line 3. The method of maintaining this rate as well as others described below is explained under "Charging Apparatus" Chapter VI. Should condi-

tions prevent maintaining the normal rate, then the rate at the beginning may be set at a value approximately 50% above the normal at the start. This figure will vary somewhat depending upon the amount of resistance in the charging circuit. As the battery voltage rises, during the progress of the charge, this rate decreases and the average charging current will be approximately the normal rate prescribed.

When the battery is not fully discharged sufficient charging need only be furnished to compensate for the capacity removed. If the cells are half discharged then half of seven hours or three and one-half hours' charge at the normal rate or its equivalent is necessary. In other words it is necessary to make the ampere-hour input about 20-25% greater than the ampere-hour output or if an Ampere-Hour Meter (Page 190) is used, set to operate 20-25% slow on charge.

The battery may be charged at any time, be the state of charge what it may, or may be discharged without other consideration than that of the capacity needed. Should a vehicle be capable of a mileage capacity of 60 miles, but 15 of which are needed per day, then a daily charge can be added sufficient to compensate for the fraction removed or no charging done until the capacity is exhausted.

Where the daily mileage is apt to vary considerably the first method is probably preferable.

Overcharge. The first charge of the battery should be an overcharge, that is charging for

twelve hours at the normal rate. This operation should be repeated after thirty and sixty days of service and after each renewal of solution. It should be understood that overcharging at the normal rate has no harmful effect at other times but is not necessary and therefore a waste of current.

Boosting. Hastening a charge, familiarly known as "Boosting" may in general be accomplished by using a high charging rate, the value of the current being governed by the temperature of the cells, a temperature of 115° being a practical limit. Experiment under many conditions has shown that the following are permissible:

	5	minutes	at	five	times	normal rate
	15	"	"	four	"	" "
or	30	"	"	three	"	" "
	60	"	"	two	"	" "

In this way noon hour or other emergency service can be obtained without injury to the cell and in fact is recommended by the manufacturer as a very efficient method of operation when the necessary charging apparatus is available. This admits of a flexibility of operation, placing the electric vehicle in a class by itself. While the battery equipment required for usual demands may not be of capacity sufficient for great mileage, yet with proper boosting, continuous operation may be obtained. A few minutes' thought will show that this is possible as there are very few vehicles which are not idle for the limited length of time necessary for the

boost. It need not be accomplished without interruption, so any time can be called the right time. Simply a matter of giving the horse a drink. To secure the best results it is not advisable to charge at less than the normal rate as a lower discharge voltage will result reducing the speed of the vehicle for the following discharge. In cold weather the charging rate should be above rather than below the normal rate in order to heat the cells before use. Where vehicles are stored and charged in a cold garage it is often found convenient to arrange the charging so that the end of the charge will terminate with the current several times the normal rate. Where a battery is to be used in a locality of exceptionally low temperature and may be allowed to stand for hours at a time, as might obtain with a pleasure vehicle, then the battery compartment should be suitably protected from air circulation so that the heat may be retained and the output of the battery thus increased. If this means be made use of, however, the compartment should be returned to its original condition when moderate temperature conditions return, as the temperature of the cells would rise above that recommended for the most efficient results through a long life.

Discharge. Very little need be said in regard to the discharge except that for continuous operation, the rate of discharge should not exceed 25% above the normal discharge rate, which is identical with the normal charge rate for the same size cell. This, of course, does not affect sudden or short overload

conditions at which there is no limit to the discharge current.

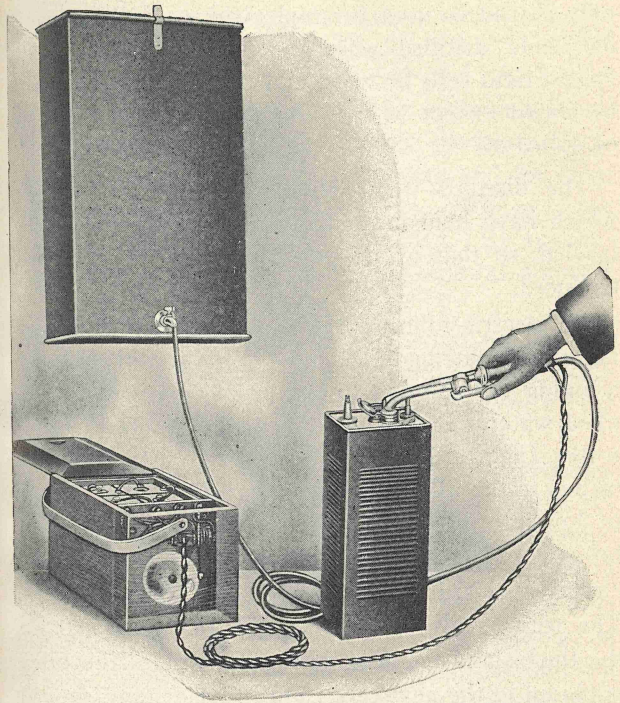


Fig. 48—Filling Apparatus for Distilled Water.

Solution. The cells as received from the manufacturer are filled with electrolyte of proper strength and (providing that no accident has occurred) to the correct level as explained above. As

the battery is charged and discharged this level is reduced owing to evaporation of solution of gassing produced by the passage of current. As this evaporation is nearly entirely water, distilled water only should be used for replenishing; never potash and only distilled water. Water should not be spilled onto cells or trays and the filler caps should be closed except when filling or testing for height of solution.

The distilled water should be kept in carboys which have held no acid and which are distinctly labeled, so that by no possibility may acid be introduced.

An electric filling outfit furnished by the manufacturer is arranged to save time and trouble in bringing the solution to the proper level with distilled water. It consists of a tank for the distilled water (Fig. 48) and a length of rubber hose attached to the filler which is designed to allow water to flow into the cell until the solution level has been brought to the proper height, when an electric bell circuit is closed by the solution and the bell rings. The spring valve of the filler is then released by the thumb and the flow discontinued until the filler is placed in the next cell. This filler or tank should be used for no other purpose than the above.

With use, the specific gravity of the solution will decrease in ordinary service, so that after a period of approximately eight months of continuous daily service or its equivalent, the solution should be tested with a hydrometer and if the readings of a

majority of the cells are below 1.160, after full charge, the solution should be renewed. The weight necessary per cell is given in (Table 10) below.

TABLE 10.

WEIGHT OF ELECTROLYTE REQUIRED IN RENEWAL

	A-4	A-5	A-6	A-8	A-10	A-12
Weight of solution to refill one cell in pounds	3	3.75	4.5	6	7.9	9.4

Having the necessary amount of solution at hand, the battery should be thoroughly discharged, removed from the battery compartment and the solution removed by inverting the trays. Sloppage over the cans and trays should be avoided. By syphoning or with a glass funnel the renewal solution should be added immediately.

For export shipments, the potassium and lithium hydrate are supplied in dry crystalline form, ready to be mixed with distilled water, according to the instructions, at the destination.

At this point in the care it is well to emphasize that cleanliness is most necessary, for neglect is responsible for the majority of battery ailments. When the trays are out of the vehicle it is well to clean them thoroughly and also to see that no foreign material adheres to the cells. Usually a jet of dry steam or compressed air will accomplish this, the former being preferable. The compartment should be cleaned out well, made tight so as to keep waste and dirt out. Where cold weather is experienced it is important that this compartment be closed tightly, so that the heat generated during charge and discharge may be retained. If the temperature of the battery fall below 50° F. on

discharge, the output will be materially lessened. The temperature of 50° F. here refers to the temperature of the electrolyte of the cell. If the compartment is properly enclosed the temperature outside the compartment may be very low, below zero in fact, without reducing the working cell temperature to the limit indicated. This capacity is accessible, however, upon raising the temperature of the cell to normal.

The highest immediate discharge capacities are obtained when the charging is carried on at a moderately low temperature, between 75° and 85° F. (not below 50° F.) and the discharge at a high temperature, not exceeding 115° F. As heat during the charge is more detrimental to the life of the plates than heat during discharge, it is recommended that the charging instructions (page 134) given above be followed as they are the result of a study of the many conditions involved in actual service.

With the above explanation, however, such variations may be made as the emergency demands or the requirements of the service dictate.

After replacing the trays in the compartment, care should be exercised in assembling correctly so that the end cells are properly connected as explained above. The contact surfaces of the connectors and tapered poles should be cleaned with fine emery cloth so that good electrical contact is obtained as poor contact would cause heating of the connection. After the cells have been on charge for a few hours, if the hand is run over these connectors, any poor connections will be found to be warm or even hot. If such is the case, the connectors should be removed, cleaned and again firmly secured.

POINTS TO BE REMEMBERED IN THE CARE OF THE EDISON BATTERY.

1. Never put acid into an Edison battery or use utensils that have been used for acid; you may ruin the battery.

2. Never bring a naked flame near the battery.

3. Never lay tools or pieces of metal on the battery.

4. Keep the filler caps closed at all times except when necessary for filling.

5. Keep the cells filled to the proper level by adding distilled water only.

6. Keep the cells externally as clean and dry as practicable.

CHAPTER VI.

CHARGING APPARATUS AND CHARGING STATIONS.

In the chapter on the subject of Storage Batteries, the words "charging" and "discharging" are used very frequently and refer to the chemical effects produced in the cells of the storage battery by the passage of electric current through them. It is necessary that this charging current must pass through the cells in one and only one direction during the charging operation. For this reason the negative terminal of the series of cells is connected to the negative terminal of the charging source and the positive terminal to that of the positive source.

In the case of a direct current charging supply these terminals when connected through the proper rheostat will supply the required charging current. With alternating current, however, the terminals are positive and negative one instant, negative and positive the next and this change continues so rapidly that absolutely no charging effect is produced on the battery. If it were not for the apparatus which transforms this alternating current into the current of one direction, direct current, then the latter only would be available for battery charging. Transforming apparatus has been developed which meets every need in this respect with the features of simplicity of operation, safety to battery and user, and efficient results. Thus we have two divi-

sions in the field of charging apparatus; that used for direct current charging and that for transforming or "rectifying" alternating current. The methods used with the accessories necessary will now be taken up under those headings. The actual operations in the charging of vehicle storage batteries are few in number and simple of manipulation, however complex the theory concerning the

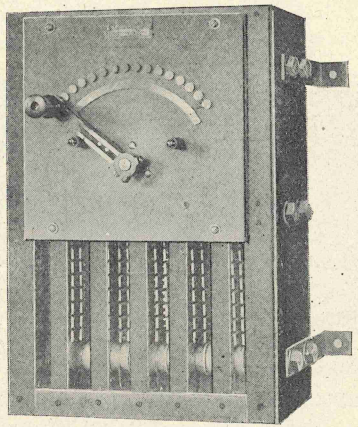


Fig. 49—Charging Rheostat for Mounting on Wall.

actions may be. The pleasure derived from the passenger car or the efficient results from the use of the commercial car are gained not by a theoretical study of the inherent parts, but by a working familiarity with the few and simple rules of conduct. It is true of the electric vehicle as it is true of electrical contrivances in general that they are simple, safe and reliable.

DIRECT CURRENT APPARATUS.

Where direct current is available it is in nearly all cases of 110 volts, 220 volts or 500 to 600 volts. These voltages will vary somewhat, but not considerably.

You remember that for charging, the cells are arranged in series and that the highest charging voltage required at the end of the charge is, with few exceptions, less than 110 volts. At the beginning of the charge, the required voltage is about 15% less than the final value so that in every case, means must be provided for gradually increasing the voltage from the lowest to the highest value required, in order that the proper charging current may be maintained. Where a 110 volt supply service is available, the introduction of a variable resistance rheostat in series with the battery is sufficient to accomplish the result.

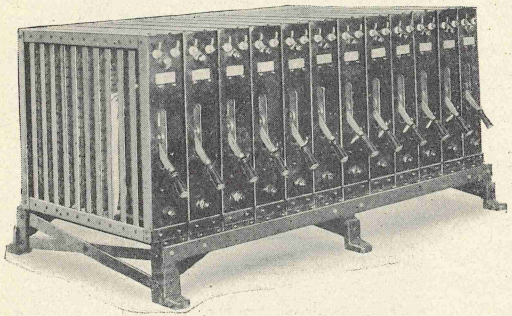


Fig. 52—Row of Charging Rheostat Units.

The charging rheostat or variable resistance is of sufficient size to carry the required charging current continuously without undue heating and is constructed so that a movement of the handle or lever lowers or raises the current, which is measured by the ammeter in convenient location for reading. These rheostats as illustrated are produced in many sizes and in several types, representing careful study on the part of the manufacturer, of the needs of the several classes of service, as private small garage, private large garage or small or large public garage. Where the garage is large, many rheostats are needed and while they may be located at one large switchboard or at the individual charging plugs, the operation of each one is simply that described above.

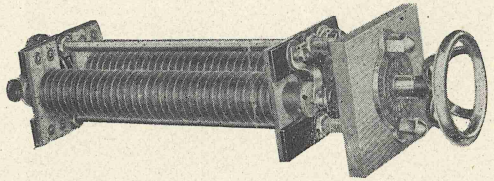


Fig. 50—Compression Carbon Disc Rheostat.

Should the voltage of the supply source be 200 volts then it will be necessary to use a rheostat with approximately twice as much resistance as for a 110 volt circuit. The loss in the rheostat is more that twice as much in this case, but is unavoidable

excepting where a motor generator set may be used as rescribed on page 176.

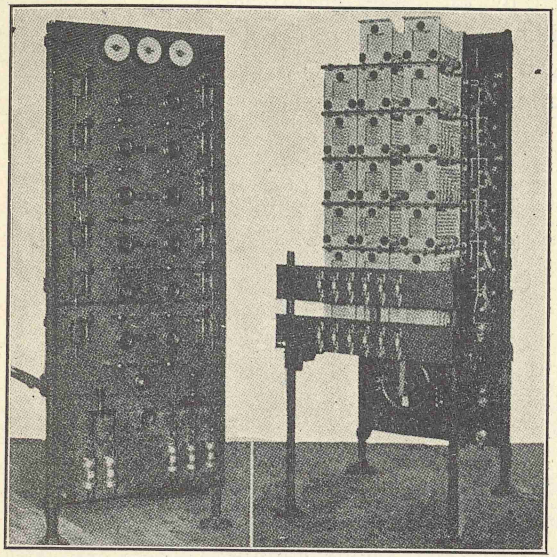


Fig. 54—Twelve-Circuit Rheostat Set for a Public Garage.

There are localities where neither 110 volts, 220 volts D. C. (direct current) or alternating current is available, but where 500-600 volts D. C. may be had from an electric trolley line. As the loss of energy, dissipated in heat in the resistance, is so large in proportion to that effecting chemical change

in the battery, this application is to be recommended only in extreme cases, such as temporary,

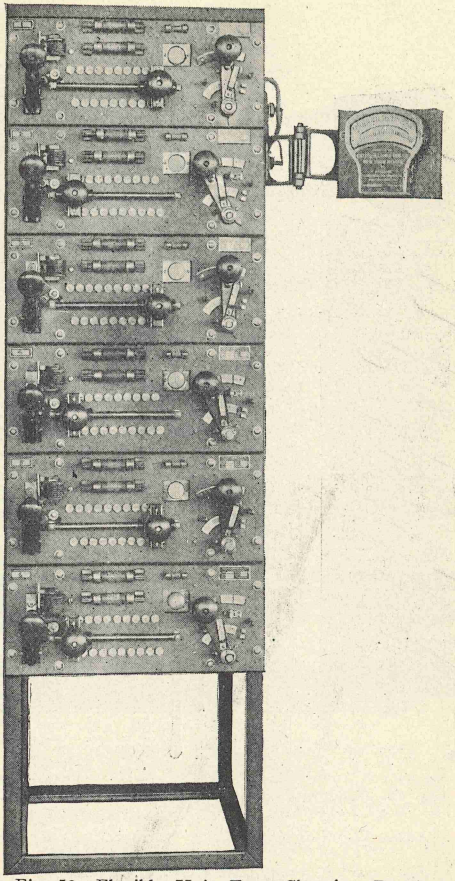
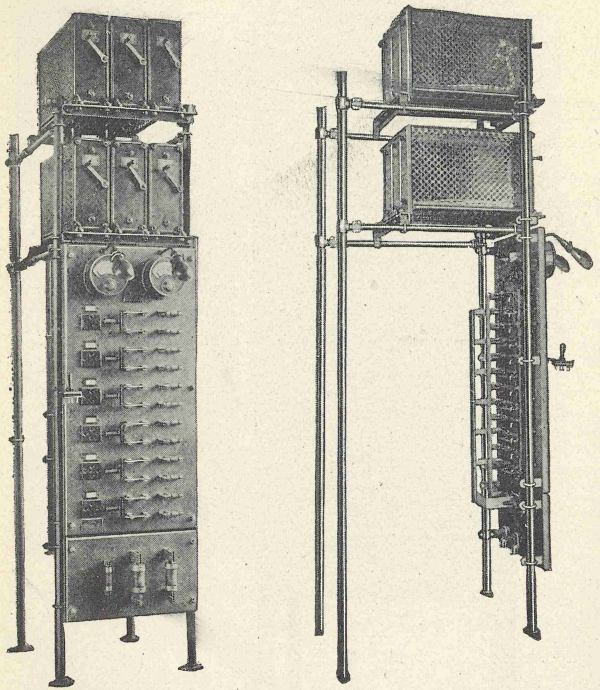


Fig. 53—Flexible Unit Type Charging Panel.

emergency or other charging applications to which there is no other alternative. It should be clearly

understood that the above statement refers to the charging of a vehicle battery from the 500 volt circuit through resistance. If the use is to be per-



FRONT. REAR.
Fig. 55—Moderate Capacity Public Garage Panels.

manent then it would be advisable to use a motor generator set (page 176). This is especially true where a number of vehicles are to be regularly

charged as the efficiency of the total installation will rise with the number of cars charged at the same time.

The rheostat is usually mounted upon an insulating slab of slate or marble and connected through

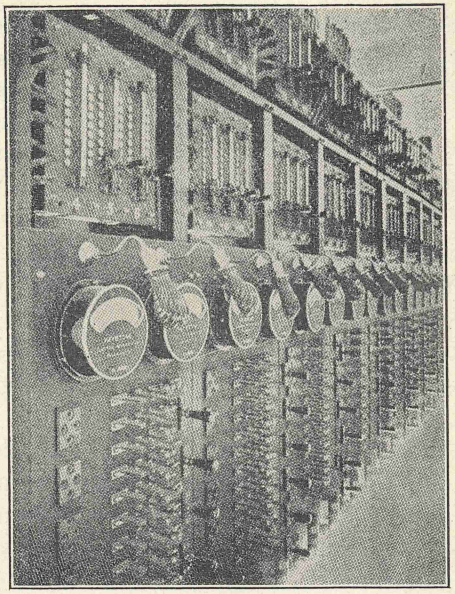


Fig. 56—Charging Board of Large Garage.

a fused switch and circuit breaker, protective devices and instruments (voltmeter, ammeter and watt-hour meter), to the battery. (Fig. 57.) The circuit breaker is an electrical device which automatically discontinues the passage of current when

it reaches too high a value. An adjusting screw fixes the value at which the flow will be interrupted. The setting is arranged to prevent excessively large current passing through the battery and ruining it by overcharge, overheating or both. The switch which cuts off all current to the battery is fused so that additional safety from too high current or short circuit may be provided. If the circuit breaker opens or "trips," it is necessary only to reduce the current and close it, but when a fuse "blows" it is necessary to insert a new one after locating the trouble. For this reason the breaker should be set to trip below the capacity of the fuse so that this inconvenience may be avoided without impairing the protection. The current passes directly through the ammeter which gives the rate at which the charging is done.

The voltmeter records the voltage across the battery terminals; the readings of voltage are those referred to in the tables (pages 50 & 135). The watt-hour meter is usally on the service side of the main switch in small installations and is not an indicating meter as are the above, but is a recording instrument giving the additive result. The difference in reading between the end and beginning of charge is the amount of energy in kilowatt-hours used. This number multiplied by the price per kilowatt-hour is the cost of the energy and can be regularly and easily checked. In many garages, one of these meters is provided for each vehicle charged, so that its energy consumption may be measured individually. The protec-

tive devices mentioned in addition to those described are an underload release (low current) cut-out (Fig. 57), maximum voltage cut-out (2) and solenoid switch (3). The low current release, automatically opens the circuit if the current falls to a predetermined minimum. This prevents the battery from discharging into the line should the voltage of the supply circuit fall below that of the battery. The maximum voltage cut-out automatically opens the circuit when the voltage of the battery reaches the voltage at which the cut-out is set to operate. In this way the charge may be automatically discontinued when completed, by setting the cut-out to trip when the battery in question has come up to the required voltage. This action would have to be dispensed with during the period of bi-weekly overcharge so that all cells can be brought up to healthy condition. The solenoid switch "makes" or "breaks" the circuit by closing or opening. It is automatic in action, remaining closed and keeping the charging circuit closed when the main switch is closed, but opening and remaining open when that switch is opened until it is again closed. This device is usually accompanied by the overload breaker (Fig. 57), so that protection is afforded to the battery under all conditions with a minimum of attention. The operation of these devices in connection with a rheostat will now be given.

Having the battery arranged for charge (page 38), all switches open and the resistance all "in" (usually with the handle to the left or at the bottom position), the charging plug is inserted in

the receptacle on the vehicle. The knife switch is then closed and the lever moved to the right to the second or third contact segment (depending on the particular make of rheostat), while bringing

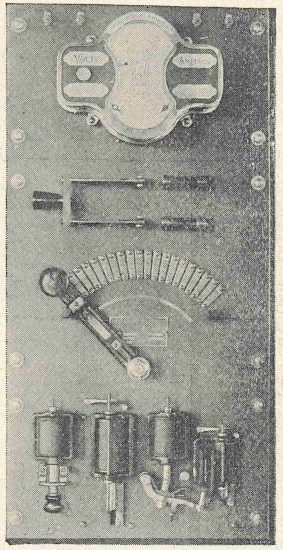


Fig. 57—Charging Panel with Protective Devices.

the plunger on the low current cut-out up into position, allowing the flow of current to energize the main line solenoid switch permitting the flow of current to the battery through the ammeter and resistance. The lever is then moved further to the right until the current is at the proper rate as indicated by the ammeter.

Should there be an interruption in the supply circuit, or the voltage of the line drop below that of the battery tending to cause it to discharge into the line, then the low current cut-out will release its plunger causing the current to cease in the solenoid switch, demagnetizing it and opening the circuit. Should the charging current reach too high

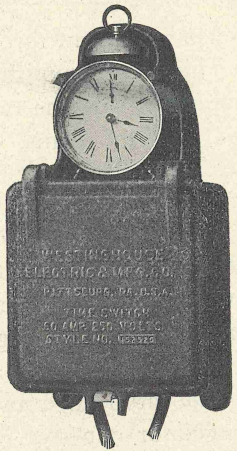


Fig. 58—Time Switch.

a value then the overload circuit breaker will become sufficiently energized to "trip" the solenoid switch, opening the circuit. Finally, if the charge progress without interruption, when the voltage reaches that at which the maximum voltage cut-out is adjusted to operate, it will "trip" and discontinue the charge, eliminating any danger of overcharge but allowing a full charge. Some devices

are arranged so as to prevent the operator placing the battery on charge except by moving the lever to the extreme left and beginning with a small current; others return the lever to the starting position as soon as the circuit is opened.

It is possible to control the current automatically by reducing the resistance in series with the battery step by step as the counter voltage of the cells increases. Fig. 59 shows a device designed to maintain a constant current throughout the period of charge. This is accomplished by means of the pointer of the meter and the relay and solenoid on the lower part of the panel. As the battery voltage increases with the charge, the current is decreased, the meter pointer travelling to the left. Adjustment made by a set screw on the instrument, permits the relay of the lower right hand corner to be energized, when the minimum current desired is reached. The energizing of the relay causes it to close the contacts of the solenoid circuit, allowing the latter to draw its plunger in, advancing the regulator one step. Each step thus cut-out increases the current rate about five amperes. This process continues until either the charge is complete or all the resistance is cut-out. When the latter condition has been reached the relay at the top of the board causes the charging circuit to be opened. This rheostat is designed to maintain a uniform charging rate and is more applicable to the charging of Edison batteries than lead batteries, which are favored by a tapering (decreasing current) charge.

The Ampere-hour Meter is described on page 190 and has come into very extended use for vehicle charging purposes. In nearly all cases it is mounted directly upon the vehicle, but the connections are arranged so that when the pointer makes the contact, when the charging is completed, the circuit breaker upon the charging panel is "tripped" and the circuit is opened. This affords a simple means of automatic charging as the battery may be put on charge at a starting rate such that the average charging current will be the same as though attendance was given at the board. This method is described on page 65. In this connection it should not be understood that no attention is required during the charging as in nearly all cases the more attention the better would be the results but a little time at the right time will obviate, in the majority of cases, the difficulties encountered.

A device known as an "automatic time switch cut-out" (Fig. 58) is frequently used for terminating the charging of a battery and is reliable and safe in accomplishing this result if properly installed. The device is merely a clock which can be set to "trip" open the circuit at a specific time in much the same manner as the alarm clock awakens the slumberer. It is to be recommended where the requirements do not exceed these qualifications. The only disadvantage is that it relies upon the intelligence of the operator to predetermine the amount of charge necessary before setting the dial. However, with a given battery, several carefully

watched charges, checking up by voltage and specific gravity readings, will readily determine the approximate length of time needed to bring the battery into a fully charged condition.

A maximum voltage cut-out (Fig. 57B) has been mentioned above and its effectiveness in operation depends upon the assumption that the voltage of the supply circuit remains constant or practically so while the battery voltage gradually increases to the limit set on the cut-out. The end of charge of lead battery is determined not by the voltage reaching a certain voltage but by its reaching and maintaining a certain maximum voltage. The latter will vary with the temperature, the specific gravity and the condition of the plates but for a given battery the change will probably be not very great from time to time so that by taking an occasional check reading with a hydrometer and voltmeter the cut-out can be made not only very useful but also reliable. In such cases where the exact conditions are not definitely known as with a new battery or when charged only infrequently at a garage, it is not well to depend upon a voltage cut-out as either under-charge or serious and harmful over-charge with attendant heating might result and entirely ruin the battery.

In the previous paragraphs practically all of the devices commonly used in vehicle battery charging have been explained. This does not mean that the battery cannot be charged unless accompanied by the use of such devices, but that they are very effective and convenient means of accomplishing the

desired result with the least effort. To summarize therefore, to charge from a direct current source it is necessary to have a suitable rheostat placed in series with a battery for controlling the current as well as a voltmeter and ammeter to measure these quantities. The voltmeter and ammeter may either be a combined instrument having the two scales or two separate instruments. When located on the vehicle the combined instrument (volt-ammeter) is used. Where the ampere-hour meter is located on the vehicle then the volt-ammeter is not usually found necessary and is located on the charging panel instead.

ALTERNATING CURRENT APPARATUS.

In order to make an alternating current available for storage battery charging it must be changed or "rectified" into current which is of one direction, direct current. When it has been thus treated its effects upon the battery are identical with those of the direct current supplied from the power station. When alternating current is rectified by means of a device which produces a current which is uniform in direction but pulsating in pressure the effects upon the storage battery are just the same as if the current were of constant and uniform voltage. The devices for changing or converting alternating current into direct current for vehicle charging are known as Mercury Arc Rectifiers, Motor Generators and Rotary Converters.

The motor generator (Fig. 67) effects the transformation in a very simple manner. The al-

ternating current supply is used to operate the alternating current motor to which is coupled a direct current generator. The generator in this case gives a direct current of the voltage required and acts in all respects similar to the generating apparatus

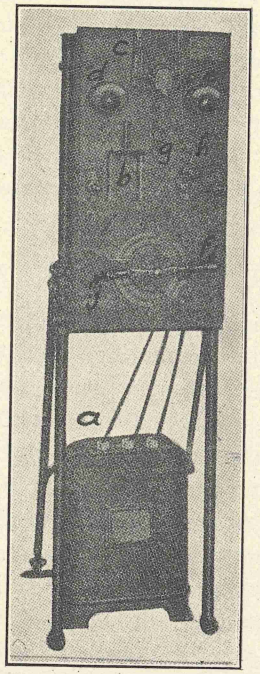


Fig. 60—Mercury Arc Rectifier.

used in the power stations. It may be varied in speed, voltage and in current out-put so as to conform to the requirements of the garage, be the number of vehicle batteries small or large. The

Rotary Converter (Fig. 68) makes use of the same principle as the motor generator with the exception that the motor and generator are combined into one machine having a common field and armature. At one end of the armature the commutator for supplying the direct current is placed while at the other end the slip-rings of the alter-

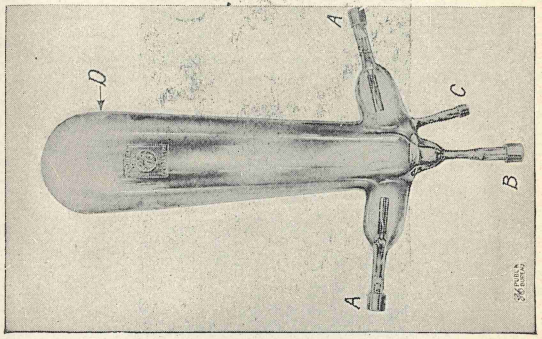


Fig. 61—Mercury Arc Rectifier Tube.

nating current motor are situated. The Rotary Converter or Motor Generator is used where a considerable number of batteries are to be charged at one time. Should but a few vehicles require charging at one time or if arrangements are such that a few vehicles may be charged at intervals, then

neither of these machines would give efficient results and the combination would best be effected by use of mercury arc rectifiers.

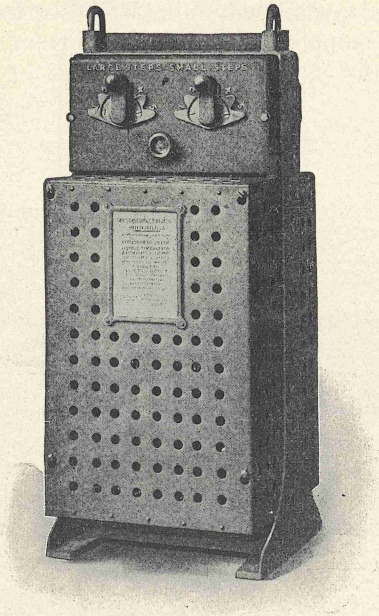


Fig. 62A—Automatic Rectifier, Front View.

The mercury arc rectifier is probably the most widely used piece of charging apparatus as the majority of central stations supply only alternating current. Its action is reliable and continuous while its operation is very simple. Any number of batteries may be charged efficiently and the equipment can be increased from time to time as the de-

mands require. For a private small garage a single mercury arc rectifier unit is used while in a large garage a number of units of large capacity operate with similar results. An individual unit (Fig. 60) consists of a slate panel upon which are placed the switches, measuring instruments and mercury tube, and an enclosed coil on the floor be-

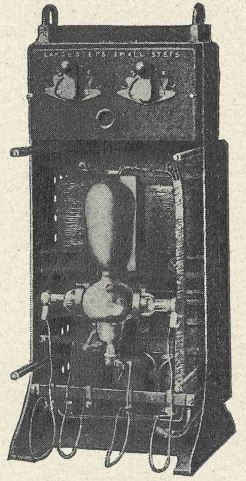


Fig. 62B—Automatic Rectifier, Cover Removed.

neath it. The leads from the alternating supply circuit are brought to the panel and connected to the apparatus through a fused switch. A cable from the vehicle is connected through a circuit breaker to the converting apparatus. The apparatus which effects the change from alternating current

to direct current consists of a large glass bulb of pecular shape as shown in (Fig. 61) and a number of coils of wire over an iron core known as reactances shown diagrammatically in (Fig. 63, F. &

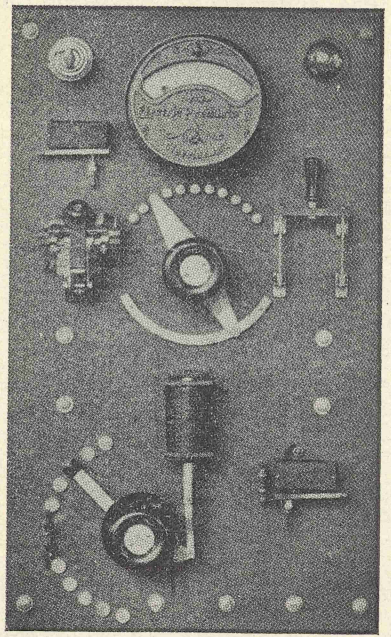


Fig. 59—Panel for Automatic Constant Current Charging.

K). The bulb is exhausted except for a quantity of mercury and is made in the shape shown to present sufficient cooling surface and to condense the mercury vapor when formed. The reactances

regulate the voltage applied to the terminals "A" and "B" so that the peculiar property of the bulb can be made use of. Current can only pass through the mercury vapor in one direction, namely, from the positive pole (anode), to the negative pole (cathode), so that as the alternating current is applied it passes during one small period of time between anode "A" and cathode "D" and during the next from anode "B" to cathode "D" and so on during successive small time intervals. In this manner as the alternating current changes its polarity an arc is sustained, without interruption, respectively between the terminals "A" and "D," and "B" and "D" giving us "D" as a permanent negative pole to which we may connect the wire to the negative battery terminal. A point midway between "A" and "B" is in the path of the current, when the arc is from A-D or B-D, and is always positive with respect to D, so that such a mid-point as "E" may be connected to the positive terminal of the battery.

In the explanation up to this point no mention has been made of the auxiliary anode "C." This anode is smaller than "A" or "B" and is used only in starting the arc. It is connected to the circuit in the same manner as the main anodes but is placed in series with a small resistance to limit the starting current. The tube is tilted so that the mercury flows from the cathode "D" into the starting anode "C," making a good circuit for the passage of the alternating current. When the current is thus established, the tube is returned to the verti-

cal position, the mercury bridge between "C" and "D" being broken. As the mercury parts, how-

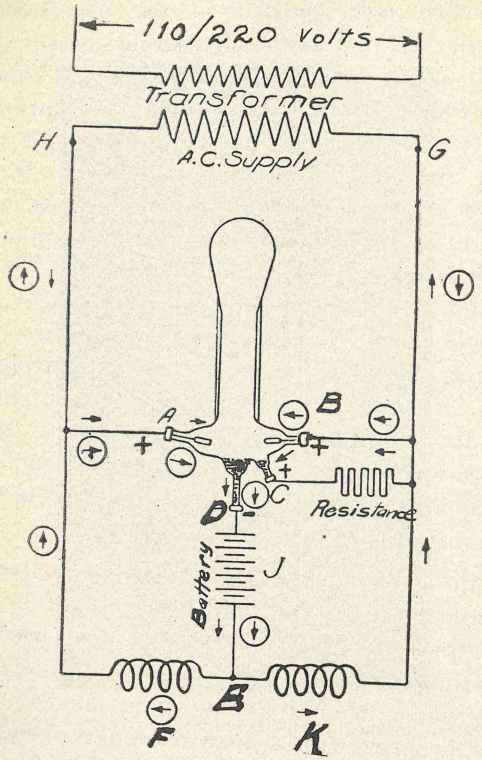


Fig. 63—Elementary Diagram of Connections Mercury Arc Rectifier.

ever, an arc is drawn between the particles, in much the same way as an ordinary arc lamp is started

by the mechanism touching the carbons and then separating them a distance designed for the proper illumination. In the case of the mercury arc, however, a quantity of mercury is vaporized, filling the entire exhaust tube. The mercury vapor thus formed is then capable of sustaining the flow of current from the main anodes "A" and "B" to "D." The current passes through the vapor in but one direction, positive electrode to negative electrode, thus giving the direct current sought. When the arc is once established the process of vaporizing continues indefinitely, but as explained, it is necessary to form the arc when the rectifier is to be started. The auxiliary electrode is used only in starting, remaining disconnected during operation. It would be possible to use one of the main anodes for starting purposes, but is impracticable because of the swing that it would be necessary to give the tube, making damage to it more likely. The tubes are made of the particular size and shape indicated in the illustrations, in order to give ample surface for heat radiation and condensation of vapor. These few words will serve to explain the theory of operation of the mercury arc rectifier in simple terms.

The manipulation of the mercury arc rectifier is very simple and requires a minimum of attention although it must be understood that in battery charging attention of the right kind is required. Exactly what such attention should be is explained under the separate headings.

As mentioned above the rectifier unit (Fig. 60) consists of the panel with the controlling devices

upon it and the reactance coil (a) encased in iron situated on the floor beneath it. Without going into details in regard to the construction of the reactance coil, suffice it to say that the connections are made and the terminals brought out and lettered for ordinary connections to the proper points on the panel. Excepting in cases where vehicles of different numbers of cells are to be charged from the same rectifier at different times no changes are necessary in the wiring of the reactance to the panel. Where necessary they may be very simply accomplished by following the manufacturer's directions. The panel of the rectifier unit which holds the meters and controlling devices, is usually of slate mounted upon pipe supports and may be encased as shown in (Fig. 57). All wiring connections are on the back of the board so that on the front there may be no confusion to the inexperienced. A main "A. C." line switch (Fig. 60b) and circuit breaker (c), ammeter (d) and voltmeter (e) in the "D. C." circuit, are usually found on the panel. The handle or dial (f) shown at the bottom of the panel is connected to a small reactance coil mounted on the rear of the panel for making finer regulation of the voltage applied to the battery. A tube mounted in a convenient holder at the back of the panel is connected by a rod extending through the board to a small knob (g) on its face so that the tube may be rocked to and fro in starting its operation. This leaves but one switch (h) upon the board unexplained. It is a special switch for the starting anode which is thrown in an up-

ward position while rocking the tube and after the arc has been formed is released and is held in the lower position by a spring.

The connections established in the operation of this switch supply the resistance and load necessary for maintaining the arc in the tube before the battery is put on charge.

It is not necessary that the panel be provided with instruments, but if the vehicle is not provided with volt-ammeter then the board should be. In all cases it is well to have the panel thus provided as the vehicle instruments being subject to shocks and jars may not be in good condition at all times.

To begin a charge at the proper starting rate, for the battery in question, inspection should be made of the panel to see that the switches are in the proper starting position, that is, open, and with the regulating handles in the lowest position then close the alternating current line switch and circuit breaker. While rocking the tube gently so that the mercury bridge between the negative terminal and the auxiliary positive terminal may be broken, place the starting switch in the starting position. The arc will then be formed and maintained in the tube after which the regulating switches may be adjusted to give the proper charging current. As the charge progresses, the adjustments of current are made by simply altering the position of the regulating switches without discontinuing the operation of the rectifier until the end of the charge. If the tube "goes out" or does not maintain the arc when the starting switch is released into the

operating position, the operation should be tried again with the setting of the regulating switch several points higher. As there are two regulating handles, one being steps of regulation of greater size than the other, adjustment should be made with the smaller or fine regulating switch until it has reached its maximum when it should be reduced

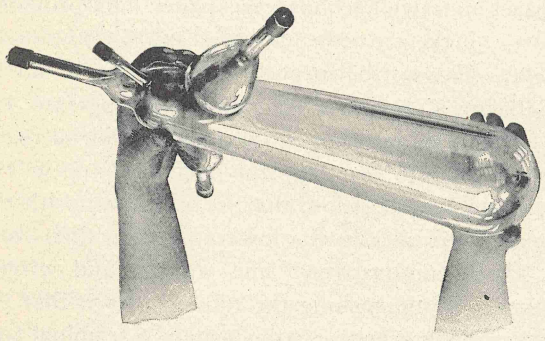


Fig. 64A—Testing Tube for Vacuum.

to its lowest position and steps of the coarse regulating switch added and final adjustment made with the fine regulating switch. By this means any voltage supplied by the rectifier from its minimum to maximum capacity may be obtained.

Should on the other hand the tube fail to maintain the arc when thrown over into the operating

position and an increase of voltage described does not effect the desired results, then the trouble is elsewhere. Inspection should be made of the connections on the back of the board to see if all are secure and if this does not produce the desired results then the tube should be disconnected, carefully removed from its holder and held in the position shown in (Fig. 64A). Giving care not to allow the mercury to run into the side arm, the lower

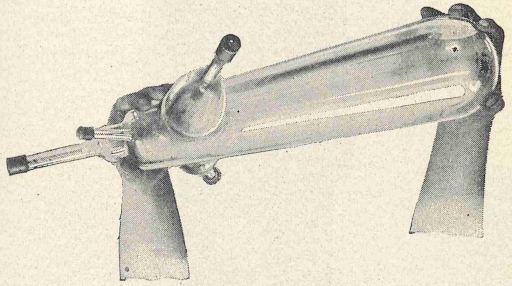


Fig. 64B—Testing Tube for Vacuum.

end should be raised (b) until the mercury rises in the large end. This operation should be done slowly so that the mercury will run in a small stream separating into drops. If the tube is in good condition the drops will come together with a sharp metallic click, but if the tube should be defective,

by reason of a poor vacuum, then the stream will be relatively slow to run and a dull thud will be heard instead of the characteristic metallic click. Should this test show that the vacuum is impaired,

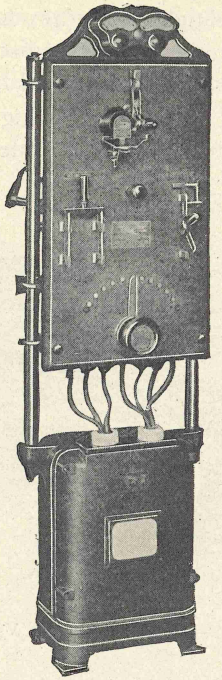


Fig. 65—Runabout Type Rectifier.

it will be necessary to communicate with the manufacturer with regard to a new tube, but if the tube is found to be in good condition then the services of a competent electrician will be required.

For the operation of a single vehicle, a rectifier set (Fig. 65), is designed to charge the number of

cells in the particular battery in the vehicle and is not adapted for charging much greater or less number. Should it be desired to charge batteries having different numbers of cells, then a rectifier unit which can be operated over a wide voltage range

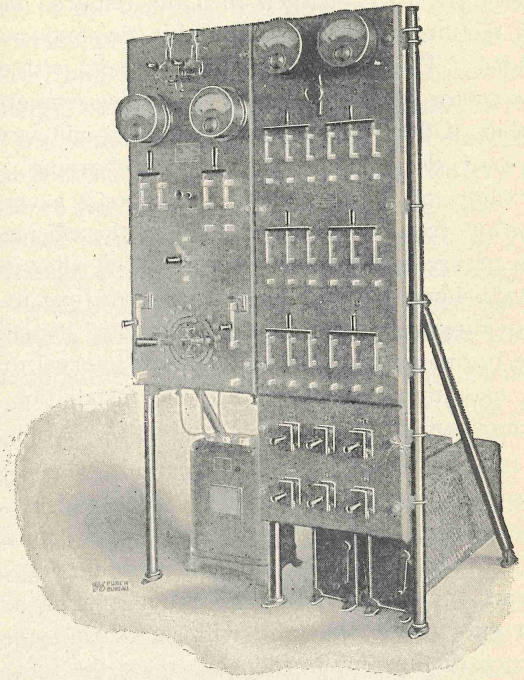


Fig. 66—Public Garage Type Rectifier.

will be most suitable. In fact, if the owner is likely to purchase a new car at any time it would be wise to install the latter or standard set so that there need be no difficulty at the time of change of cars.

For garages handling a number of vehicles,

whether of the pleasure or commercial type, the rectifier units (Fig. 66), will prove very satisfactory, flexible and efficient. If but one car is to be charged at a time, but one rectifier unit need be run while on the other hand if a number of batteries are to be charged then the required number of rectifier units to supply this demand may be added. This feature does not obtain with either the motor generator set or the rotary converter as either of these machines operate as a unit irrespective of the number of batteries charging. This flexibilty of the mercury arc rectifier is a very important feature, not only affecting the efficiency of the garage apparatus in operation, but allowing the establishment to add equipment from time to time, providing, of course, that the estimated demands at the beginning or after a reasonable interval of time of operation do not require the installation of a motor generator set.

It requires a certain dissipation of energy to maintain the arc in a mercury tube which is evidenced in the form of heat and a small quantity of light. The voltage required to maintain this arc is about 15 volts and is practically constant for all currents which the tube will stand, thus the efficiency of the rectifier depends upon the total voltage delivered to the battery or in other words, the greater the number of cells charged within the limits of the rectifier the greater will be the efficiency. In practice this efficiency increases from 70% at 60 volts D. C. to 80% at 175 volts D. C.

The life of the bulb is approximately 600 hours

but with proper care should give considerably more. This is practically the only part of the apparatus which will wear out under normal average use.

Reference has been made under the head of Direct Current Apparatus to the automatic controlling of the charging and this feature is possible also when charging from alternating current. Rectifiers may be arranged not only to discontinue the charge, but to start automatically if the current from the supply circuit is interrupted before the end of the charge. The voltage of the battery increases to the point at which the charge may be considered final. The rectifier is adjusted to give this voltage but no greater so that these voltages, being equal and opposite balance each other and do not allow a voltage sufficient to maintain the arc.

The tube then ceases to operate, thus disconnecting the battery. The automatic starting when the charge has been interrupted is accomplished by means of a device designed to rock the tube reestablishing the arc. These features are inherent in the rectifier and may be supplemented by the use of time switches, ampere-hour meters or the devices which have been referred to in the previous paragraphs. While the automatic features are effective under good conditions and are designed to meet the ever-increasing demand for better results with less labor and attention, their use should be tempered with common sense so that a small amount of care, which must be given if satisfaction is to be obtained, should be exerted at the right time.

The mercury arc rectifier is usually operated

from a single-phase alternating current circuit, but is manufactured also for use on three-phase circuits. The frequency upon which the mercury arc rectifier will operate may be from 25 to 140 cycles with slight changes in the apparatus. The voltage impressed is either 110 or 220 volts. Higher voltages than these may be easily reduced to these values through suitable transformers. The maximum current which a single tube is capable of giving, at this writing, is 50 amperes at continuous

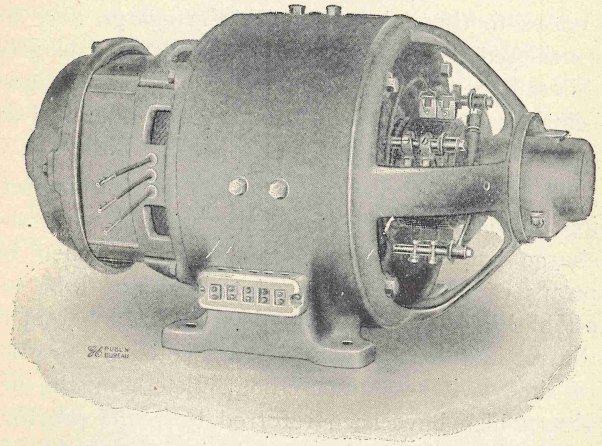


Fig. 67A—Motor Generator, A.C. Motor, D.C. Generator.

operation. Larger currents than this are obtained by arranging a number of tubes in parallel by means of an auxiliary control panel.

MOTOR GENERATORS.

The motor generator has two applications in vehicle charging, namely, changing direct current of

a high voltage to 110 volts or less (Fig. 67A) and for changing alternating current to direct current of suitable voltage (Fig. 67B). In speaking of direct current voltages, 220 volts and over, it was recommended that it was very much more economical to install a motor generator set than to charge through a resistance on account of the great loss in the rheostat. Where charging is temporary or infrequent this condition will of course not apply, but in nearly all cases it will be found upon calculation that it is more efficient to use the set. The efficiency will increase directly with the number of vehicles charged at the same time from the gen-

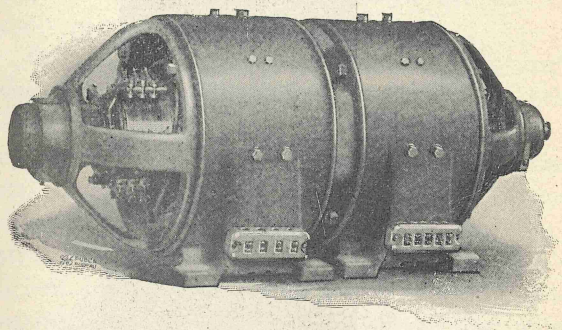


Fig. 67B—Motor Generator Set, D.C. Motor, D.C. Generator.

erator. It is often found advisable to operate the motor generator when the load is heavy, that is, a considerable number of cars charging and to shut it down and charge from a few rectifiers when the number of cars is not sufficient to justify the operation of the motor generator with economy.

Rotary Converter. This piece of machinery

produces the results effected by the rectifier and the motor generator set, but usually requires a larger

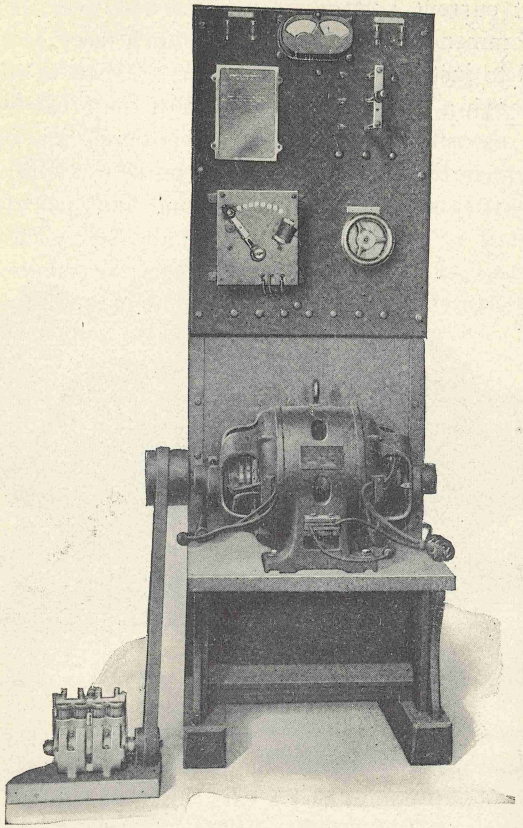


Fig. 68—Single-Phase Converter, with Tire Pump Attachment.

number of cars to be charged for efficient results.

A form of converter designed for use on single

phase circuits with high power factor is shown in (Fig. 68). It can be furnished in sizes capable of charging any number of batteries up to a demand of 10 kilowatt capacity. The illustration shows a converter designed for charging a single vehicle battery. A pulley attached to the shaft permits the operation of a small tire pump, which is a useful accessory.

Mechanical and Synchronous Rectifiers. Considerable experimenting has been made upon mechanical, chemical and synchronous rectifiers, but up to the present time they are available only for rectifying currents of small amperage, not being adapted to the charging of electric vehicles, especially in numbers.

Boosting. Hastening a charge or "Boosting" is very often a feature of value in electric vehicle operation, and if there is any likelihood of high rate charges being necessary, the charging apparatus installed should be capable of maintaining the required current without undue heating. Not only the instruments and resistance should be of capacity, sufficient to operate under these conditions, but all wiring on the charging panels and vehicles as well.

Temperature is a limiting feature in storage battery charging. The current is limited only by the maximum allowable temperature (page 51) and the gassing. For lead batteries the gassing should be kept a minimum at all times; Edison cells are not affected by the gassing, temperature only requiring consideration. The necessity for boosting is practically eliminated in the small private

garage, but in public garages is a very important feature and it is safe to say that current in excess of two hundred amperes from a charging plug could be utilized for this purpose, in maintaining vehicle operation during adverse weather and road conditions. For this reason this item should be considered in the choice of apparatus for an installation.

The word "Booster" is used in another connection, and designates a direct current generator of low voltage but of ample current carrying capacity. It sometimes happens that the direct current voltage supplied is 110 volts and that 60 cells of Edison battery or 44 cells of lead battery, requiring 110 volts, are to be charged. Should the line voltage be less, however, or it be required to increase the rate by increasing the voltage then the booster would increase the voltage the desired amount, carrying the current so dealt with through its armature. This use is resorted to in some cases when the capacity of the existing apparatus is found inadequate in the above respect, rather than install a new equipment. Excepting for this use in vehicle battery charging there is little occasion for the use of a booster, its application being confined in most cases to large lighting battery installations.

ISOLATED PLANTS

As a general rule it may be said that, except in very few cases, the isolated plant cannot compete with the central station in supplying current for vehicle charging. This applies both to the price and flexibility of the service rendered. There are peculiar conditions existing in some localities which

do however merit the use of a steam or hydro-carbon engine and generator.

Should no power be available from a central station, as obtains with some farms, country homes, hotels or factories, then the problem resolves itself into the choice of the proper size of electric outfit, as electric light and power for kindred devices are demanded in most cases. Usually a 115-125-volt generating set, gasoline or oil engine driven, will be found thoroughly satisfactory and economical, providing that apparatus designed for this use is installed. Makeshift combinations of engine and generator, ill suited to combined operation, can hardly be recommended as the little attention given, and the probable absence of expert service in time of need, would make the results not only unsatisfactory, but more costly in the long run. The capacity of the equipment should be determined with regard to the future requirements as well as the present needs. It is impossible to lay down a fixed rule as no two problems will be identical. The manufacturers of recognized equipments may be relied upon to effect a simple and economical solution and will gladly offer their services.

Charging Stations. Communication with the central station companies supplying electricity in the larger cities of the country has shown that there is at present an abundant supply of charging stations, and that the number is constantly increasing at a very rapid rate. The names and locations of these stations change somewhat from time to time so that a list of the 700 and more public charg-

ing stations distributed over the United States is not appended. Definite information as to the names and locations of these stations may be readily secured by communicating directly with the central station company supplying the district concerned. In practically all cases the electric lighting and power companies have these lists, supplemented with road maps and other attractive information of local character. The Electric Vehicle Association of America (see p. 308) maintains a bureau for the dissemination of such knowledge, and communication will bring forth the desired information.

The number of public charging stations given above includes only those which operate for public garaging of electric vehicles The large number of private commercial installations, such as breweries, express companies, department stores, grocers, etc., owning fleets of vehicles garaged in their own installations, are not included The number of electric passenger vehicles is increasing very steadily, and as the small private garage with charging set adjacent to the residence is attractive and convenient, the number of private garages for pleasure cars will be found to be several times in excess of the number given for public stations.

When the electric is to be charged at a station other than its regular garage, a plug should be carried so that the necessary wiring arrangements may be conveniently secured, and the capacity and charging rates of the battery should be recorded and carried for convenient reference.

CHAPTER VII.

MEASURING INSTRUMENTS: ELECTRICAL AND MECHANICAL.

In the explanations of operation and instructions for the care of practically each item of the electrical apparatus concerned with the electric vehicle, reference has been made to the electrical quantities, current, potential, resistance and power. These are measured respectively in terms of the units, amperes, volts, ohms and watts. The unit of electromotive force (the volt) will cause unit current (one ampere) to flow in a circuit of unit resistance (one ohm). This expression is a simple but fundamental equation of electrical phenomena and is called Ohm's Law. From it are derived, by the application of proper mathematics, all of the whys and wherefores of modern electrical engineering. For the purposes of this book, however, it is unnecessary to complicate matters with these technicalities. The simple relation given above is sufficient for an understanding of the usual manipulations incident to electric vehicle operation.

The flow or passage of current in a circuit produces a definite amount of power, which is measured in watts. The watt is the product of one volt and one ampere. The kilowatt is 1,000 watts. Thus the amount of energy available in one hour, when the power exerted in one kilowatt, is one kilo-watt-hour.

These quantities defined in terms of the units are very readily measured by means of the electrical

measuring instruments, ammeter (ampere-meter), voltmeter, ampere-hour meter, and watt-hour meter.

Voltmeter. The voltmeter indicates the difference of potential, or voltage, of any number of cells of the storage battery or of the supply circuit from the power station. The magnitude of the voltage to be measured determines the range of the instrument. The scale of the instrument depends upon the voltages to be measured normally and the highest which may be measured. The scales usually used are 0-3, 0-15, 0-110, 0-150, 0-250, and 0-300 volts. The scale shows the maximum voltage for which the instrument is to be used, as higher voltages would send too much current through the fine wire of its coils and burn them out. The meter measuring up to 3 volts is used for indicating the voltage of individual cells of the battery and should not be used on more than one cell. A meter of 150-volt range is suitable to measure any voltage up to 150 volts, such as the complete battery voltage or the voltage of a charging circuit of 110 or 125 volts. If the wiring be of the three-wire system having 230 or 250 volts across the outside wires, then it is evident that the meter should be used only between the neutral and the outside wires, and not placed across the 250-volt potential. For the measurement of this voltage, an instrument having a 300-volt scale should be used.

The scale is a part of the instrument, is calibrated and is correct for its own instrument only. The question might be asked if placing a 0-150-volt scale on a 0-3-volt meter would permit the measuring of potentials up to 150 volts. From what has been said above it should be clear that such cannot be done as the wiring of the instrument is sufficient only for 3 volts, as indicated by the scale. Meters are constructed, however, having a coil for each voltage range required so that two or three instruments may be combined into one. Figure 69 shows such an instrument with triplex scale.

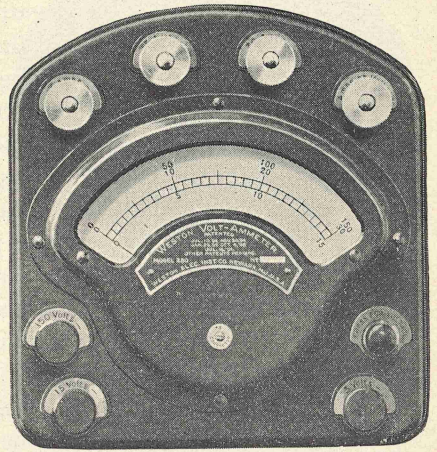


Fig. 69—Portable Volt-Ammeter with Triplex Scale.

The leads of a voltmeter are thin flexible copper insulated wires attached to the positive and negative binding posts of the meter. The free ends are then applied to the source whose potential is to be measured. Both leads must first be secured to the meter binding posts before the free ends are used in order to avoid damage from accidental

short circuit. The same positive meter terminal is conventionally used for each of the scales when the instrument has more than one. Care should be taken, when the voltage to be measured is not approximately known, to use the high voltage scale to determine the reading roughly so that danger of burning out the low reading coil may be avoided.

The lead from the positive binding post, which is marked (+), should be applied to the positive wire or pole of the battery, and the negative lead upon the negative pole, respectively. Where the voltmeter is used as a means of determining which is the positive wire or tracing out connections, then the positive lead should be held fast to one pole and the end of the other lead tapped on the supposed negative pole. The pointer should be carefully watched when the lead is tapped. If the pointer reads in the right direction, that is, gives a reading on the scale of the instrument, then the assumption of positive and negative was correct. Should the pointer indicate in the wrong direction, however, then the position of the free ends of the leads should be reversed immediately, as a violent throw of the needle in the wrong direction would be very likely to bend it.

The remarks in the preceding paragraphs are general, applying to portable as well as switchboard or dashboard types of meters. Switchboard meters, of course, when once placed in position require no change of connections as they are made on the back of the board so that, when the switches are closed, the voltmeter will indicate. On large

switchboards consisting of a number of circuits, it is usual to use one voltmeter and one ammeter for each panel of six circuits, a selective dial allowing the voltage of each circuit to be read.

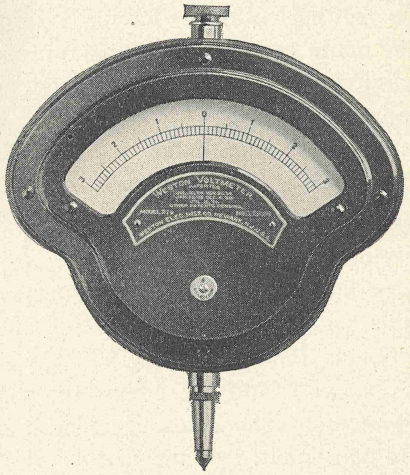


Fig. 70—Battery Testing Voltmeter.

In order to secure accuracy in electric measuring instruments, it is necessary to have them extremely well balanced. This is accomplished by making the moving system as light as possible and pivoting it upon polished jewels. The instrument is thus as delicate as a watch and so should not be handled roughly. As to making adjustments, it may be said that unless such are explained and recommended by the manufacturers they should not be

attempted. It is preferable in the majority of cases to place the instrument in the hands of a competent instrument man or return it to the manufacturer for a small repair rather than to meddle with it and then send it for complete overhauling, as would probably then be necessary.

The low reading voltmeter having a 3-volt range is made in many convenient forms for use in going over individual cells, on charge and discharge or for cadmium readings. Care should be exercised in the use of such a meter as its usefulness depends upon its accuracy, Fig. 70.

The voltmeters placed upon the dash, or in any other convenient location in the vehicle, are usually combined in one case and on the same base with the ammeter, so that both may be easily and simultaneously noted. They are made as rugged as possible so as to withstand the effects of travel over rough pavements. The leads are placed so as to give the voltage applied to the motor, whether the battery is in series or in parallel, during the discharge. On charge the cells are practically always charged in series so that the voltmeter then gives the voltage applied across the battery in charging.

As explained under "Storage Batteries," there is a maximum voltage reached on charge and a safe minimum voltage on discharge with normal current flow. These amounts may be, and often are, indicated on the scale of the meter in red lines by the vehicle manufacturers so that they may be readily observed in charging or during operation.

Ammeter. The instrument used to measure the electric current in amperes is the ammeter. It is very similar to the voltmeter in construction, but is placed in series with the circuit instead of across it, as shown in Fig. 71. What has been said of the scale ranges of voltmeters is also true of ammeter scales, and care should be taken to see that currents

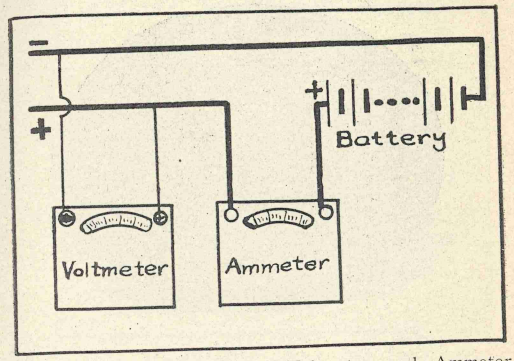


Fig. 71—Method of Connecting Voltmeter and Ammeter in Circuit.

in excess of the scale range are permitted only for very short periods, as damage to the meter would otherwise be likely to result. Ammeters used in storage battery work generally have a zero centre scale, as shown in Fig. 72, so that no change of connections need be made when reversing from charge to discharge of the battery. It would otherwise be necessary to do so, as the current flows in opposite directions in charge and discharge.

The ammeter measures the current flowing through a special resistance, known as a shunt, Fig. 73, which may be located within the ammeter case or external and separable from it. Care should be taken to use the meter only with the shunt furnished with it, unless specified otherwise by the manufacturer, as the meter would not give correct readings and might be damaged.

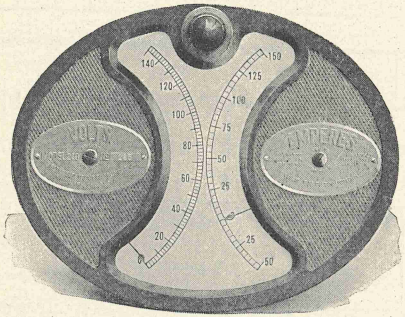


Fig. 72—Vehicle Type Volt-Ammeter.

The combined instrument, voltmeter and ammeter, Fig. 72, when assembled in one case for vehicle service, is generally spoken of as a volt-ammeter, and has met great favor in giving the information required in the operation of storage battery vehicles.

The Ampere-Hour Meter. The voltmeter and ammeter are indicating instruments which give the instantaneous values of the voltage and current of the circuit. In practical storage battery operation, however, it is very convenient to have more in-

formation than the instantaneous value of current or voltage because, what the operator of an electric vehicle is most interested in, is the mileage capacity of his battery. When starting out with the battery fully charged it is known approximately how many miles the vehicle can be run upon a charge, but, if the operation is discontinued and the car allowed to stand or a routing selected which differs from that previously gone over, then the latter part of the discharge will not be definitely determined as to completeness for the operator.

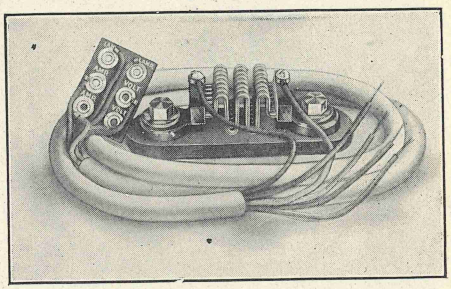


Fig. 73—Ammeter Shunt and Leads.

Readings of voltage at a definite current flow from the battery will give a very close idea of the state of charge in the battery, but, to the inexperienced or when the instruments are not in good condition, the results are not always satisfactory. Readings of specific gravity are the most reliable and at all times give an absolutely correct determination of the state of charge in the battery. Owing to the method off taking these readings, it is evident that such indications are not practical for ordinary vehicle operation, and that some sort of meter, which will record the current which has been put

into and taken out of the battery, is needed. Such a meter is known as the ampere-hour meter, Fig. 74, and is designed to measure the current put in or taken out of the battery, but does not take account of the internal discharge of the cells. This latter point should be clearly understood, for, should a fully charged battery in a vehicle be allowed to

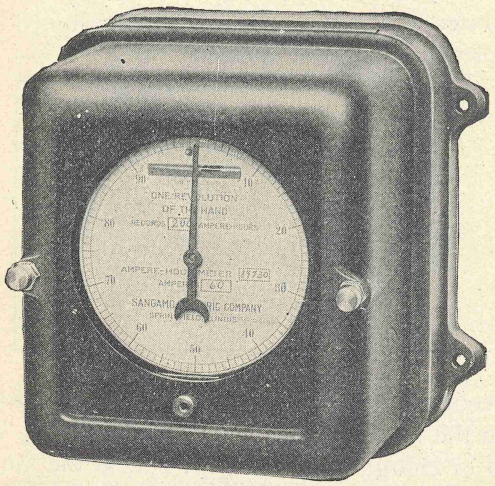


Fig. 74—Ampere-Hour Meter.

stand for a considerable length of time, owing to internal discharge, the capacity would be gradually reduced, although this effect would not be recorded upon the meter since the only current registered on discharge is that used for operating the vehicle which is regulated through the switches and controller. In case the battery is allowed to stand for

a long period without use it should be recharged independently of the meter reading, and the full charge determined by noting the rise in voltage, or, in the case of a lead battery, by testing the specific gravity.

The ampere-hour meter is of the Faraday motor type, which depends in principle of operation upon

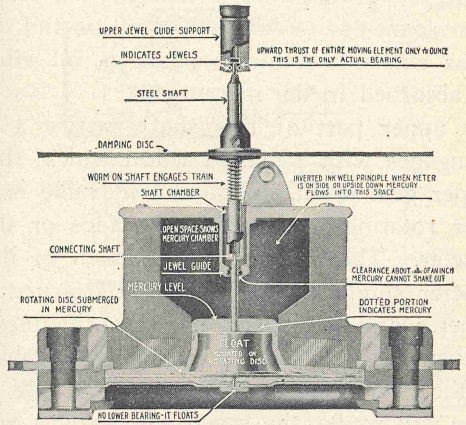


Fig. 75—Cross-section of Motor Element of Meter.

the action of a magnet upon a copper disc armature free to rotate while carrying current. The sectional illustration (Fig. 75) shows the construction of the meter with the permanent magnet omitted so as not to complicate the drawing. The armature disc in this instance is of copper, rotating, and submerged in a chamber of mercury. The current is conducted to and from the disc by contacts im-

bedded in suitable insulating compound in the walls of the chamber. The mercury carries the current from the contacts to the armature, and also produces an upward thrust on the axis of the armature so that there is no pressure on the lower support or bearing, and only a slight pressure on the upper support which is practically the only bearing. With this construction the manufacturers claim a high degree of accuracy combined with freedom from accident due to constant vibration and jarring such as exists in vehicle operation, all vibration being absorbed in the mercury.

The upper part of this shaft carries a worm that engages with a geared wheel which, through a proper gear train, operates a movable hand or pointer rotating in front of the face or dial of the meter. The current, or a portion of it from the meter shunt, passes through the armature of the meter and is reacted upon by the powerful, permanent, driving magnet, so that in combination with the gear train, mentioned above, the large pointer will rotate, the speed and amount of rotation depending upon the current flowing and the time. The voltage is not in any way recorded since we are interested particularly in ampere-hours.

Proper use of the ampere-hour meter will obviate unnecessary charging and overcharge as well as overheating. It is easily read and precludes the necessity for paying attention to the observation of voltage and specific gravity during discharge.

In the case of the lead battery, the specific gravi-

ty is a definite indication of state of charge, but in Edison batteries it tells very little so that the meter is found to be even more useful with the alkaline battery than with the lead battery.

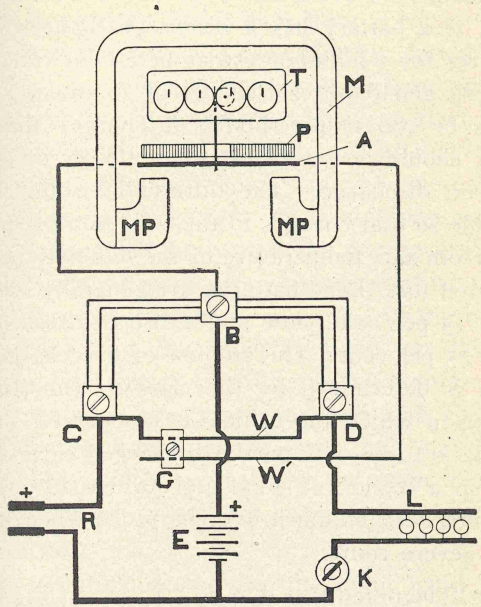


Fig. 76—Diagram of Differential Shunt.

The meter equipped with a single shunt records the true ampere-hours charged into the battery and those drawn from the battery. It does not take into account, however, the fact that it is necessary to put more ampere-hours into the battery than can be removed from it in any succeeding discharge. In order to compensate automatically for this in-

efficiency, an arrangement known as a "differential shunt" is incorporated within the meter allowing a percentage overcharge to be given. This percentage is adjustable as the slider "G" (Fig. 76) can be moved from 10 to 30 per cent. variation. Thus if a battery has a discharge capacity of 30 amperes for 5 hours or 150 ampere-hours discharge capacity and requires a charge of 30 amperes for 6 hours or 180 ampere-hours of charge, then the meter should be set 20 per cent. slower on charge than on discharge. The differential shunt is adjustable so that changes in the condition of the battery from age, temperature or the like may be compensated for. Lead batteries are generally set from 10 to 15 per cent. slow and Edison batteries from 15 to 25 per cent. The amount of overcharge thus given is determined by the class or condition of service in which the vehicle is to operate. If the vehicle is to be only partly discharged each day or used in a section of good and level roads, then it does not need as much overcharge as when it covers a severe route.

It will be noted that there are two methods which may be employed in showing the recording on the meter dial. One is to have the hand move clockwise on discharge and counter clockwise, or back to the zero point or top of the dial, on charge, while the other is to reverse this sequence. The advantage of the former is that the position of the hand at any time during discharge shows exactly how many ampere-hours have been taken from the battery, and, when the pointer reaches the zero

mark in charging, then use may be made of a zero contact or "stop charge" feature. The second arrangement mentioned does not allow of this automatic feature, but gives a direct reading of the amount still available in the battery.

The instructions which have been given in Chapter III. on the care and operation of storage batteries are not affected by the use of an ampere-hour meter, and precautions which are given there are not to be abridged with the use of this instrument. As explained above, a slight internal loss takes place in the battery while standing so that, if the battery has been standing for several days and full charge is required before starting out, it can be given to the extent described in the battery instructions, and the movable hand set back to zero or full charge position. The regular overcharge which is prescribed for both lead and Edison batteries should also be given, and may be accomplished readily by resetting the main hand the desired number of ampere hours before beginning the charging.

The resetting device for the main hand is absolutely necessary for a meter not provided with the differential shunt inasmuch as the required overcharge must be set by hand at each charge. When the differential shunt is used, however, then the resetting device, while not necessary for ordinary charging, may be found very useful for the regular overcharge every two or three weeks, or when a new battery is substituted for the one which has been operating in the car, and the position of

the hand on the dial is not "in step" with the battery, that is, when the pointer does not give the true condition of charge in the battery. By this means it is possible to arrange the pointer so that,

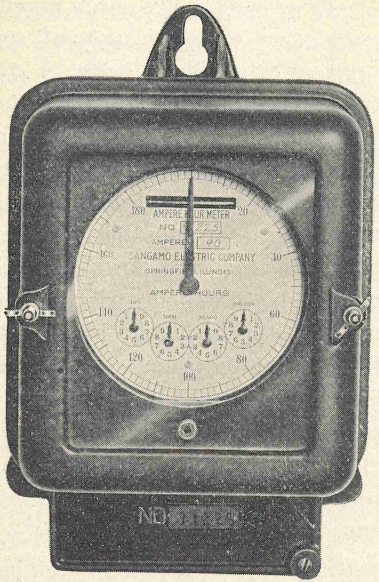


Fig. 77—Service Type Ampere-Hour Meter, with Totalizing Circles on Dial.

when it reaches the zero mark after allowing the required charge, it will operate the zero contact feature and discontinue the charge automatically. The manufacturers have furnished the device with a cap so that tampering by unauthorized persons is avoided, and injury by jamming or stripping of

gears in the clockwork while resetting is prevented.

The zero contact or stop charge feature, which has been referred to in preceding paragraphs, consists of a contact at the zero point on the dial operated by the pointer. When the pointer is revolved back to the zero position indicating that the battery is fully charged, then the contact completes a circuit to a circuit-breaker, which causes the latter to open, discontinuing the flow of current through the battery to which the meter is connected. This device depends only upon the ampere-hours and not upon the voltage of the supply circuit or the battery, differing from the method employed in the mercury arc rectifier, where the current is reduced as the effective voltage deceases as the charge progresses. This is a very convenient feature in many instances, among which may be mentioned the small private garages in which a pleasure vehicle may be placed upon charge late in the evening, or after reaching home from the theatre, and the charge automatically discontinued during the night or early morning, according to the amount required, without necessitating further attention from the owner.

The dial of the meter is graduated in ampere-hours and the unit number of ampere-hours, per revolution of the hand, should be somewhat more than the greatest discharge capacity of the battery, so that, if it be required to give an overcharge, making use of the resetting of the main hand, the complete charge in ampere-hours may be indicated upon the dial. Sometimes a second hand is added,

turned by means of a knurled head at the centre of the glass in front of the dial. This hand is not connected with the main hand or mechanism of the meter in any way and is used only by the operator in being set at an arbitrary reading of the dial for

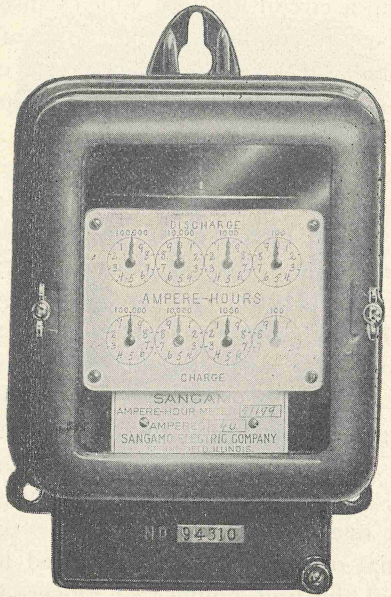


Fig. 78—Ampere-Hour Meter, with "Duplex" Recording Train.

reference such as the maximum safe discharge capacity. Thus as the battery increases in capacity during life, the position may be changed using a gradually increased reading as the safe maximum discharge.

As explained above, the large hand operates through suitable gearing, and, as it rotates at a speed proportional to the ampere-hours, it will indicate the ampere-hours input or output, depending upon the direction of rotation of the pointer.

This large pointer gives the condition of charge for one cycle of charge or discharge, as it operates in one direction for charge and in the reverse direction for discharge.

In addition to this pointer a recording train is sometimes included, Fig. 77, this being so connected to the pointer through suitable gearing that it will record the total ampere-hours of charge or discharge during several cycles, or for any considerable period.

For special cases it is possible to furnish a dial, termed by the manufacturers the "Duplex Train," Fig. 78, arranged to record the total of both charge and discharge. In using this arrangement, however, it is not possible to use the large pointer to indicate the condition of the battery for each individual charge and discharge. For any given voltage the readings of charge may be calibrated upon the dial in kilowatt hours instead of ampere-hours input. In connection with an odometer or other mileage recording device, complete and detailed results may be thus obtained by means of such a meter.

The ampere-hour meters are constructed in two general types known as the self-contained meter and the distant dial meter. The first named is manufactured in three styles, called the Auto type,

the Service type and Extension Front type. Electrically all three of these are identical, the differences being only in the arrangement of the base casting upon which they are mounted and the special way in which the leads are brought into the meter.

The Auto type is supported upon an aluminum base and is intended for location in passenger vehicles in position for easy reading.

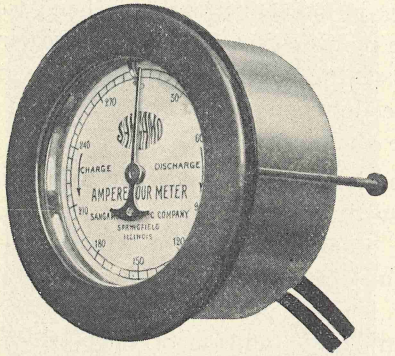


Fig. 79—Distant Dial Mechanism.

The Service type is slightly larger than the Auto type and is mounted upon a solid cast iron base with bottom connecting box through which the leads are brought in and secured.

The Extension Front type is contained in a pair of aluminum castings so arranged that the meter is supported by lugs at the front, allowing the dial, with friction tight bezel ring and cap only, to protrude through the heel or dashboard.

In some cases it is not convenient to place the meter, in the forms described above, in the most suitable location in the car body on account of the space it would occupy and the heavy wires leading to it. To meet this demand the manufacturers supply a meter of the Distant Dial type. This arrangement allows the meter proper to be placed out

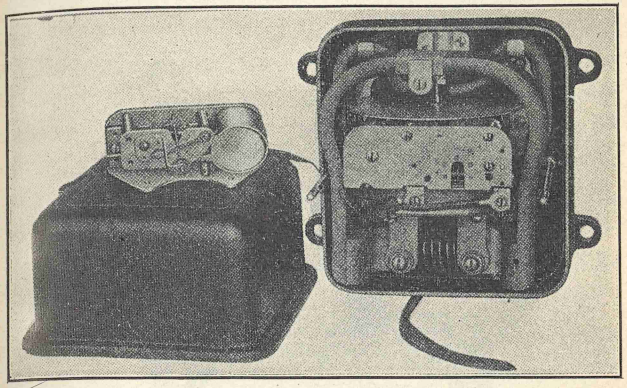


Fig. 80—Distant Dial Type Ampere-Hour Meter and Contact Train, Cover Removed.

of the way, as beneath the seat or supported on the chassis. The dial mechanism may then be located within the body of the vehicle at the most convenient spot. This dial mechanism is furnished in the flush or projecting type as shown, Fig. 79.

OPERATION OF CONTACT MECHANISM AND DISTANT DIAL.

Instead of the recording mechanism as described for the standard meter, in which the shaft drives a hand, a contact train, Fig. 80, is

provided which closes a contact to the distant dial mechanism at equal intervals of ampere-hours measured by the meter. The dial mechanism consists of two electro-magnets facing each other, and provided with a lever free to rock between them. The energizing of one of these attracts the lever on charge, the motion thus imparted advancing the hand one division on the dial toward the zero

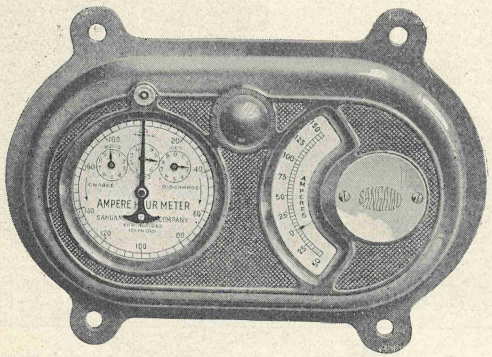


Fig. 81—Ammeter and Distant Dial Mechanism.

point. During discharge a similar series of impulses through the other electro-magnet change the position of the dial hand in the opposite direction from that travelled during charge. Should the leads connecting the contact-making mechanism with the dial mechanism be broken, the meter proper would not be affected, as the rotation will continue, the driving wheel of the contact train simply escaping past the bar operating the contact in either direction.

The zero contact feature is provided in the distant dial type as well as the standard type of meter, so that an auxiliary circuit breaker may be operated, opening the charging circuit.

Leads and cables connecting the meter and dial to the charge and discharge circuits are furnished in distinct colors so that, with the diagrams, the proper connections may be readily effected with small opportunity of error.

Ammeter and Distant Dial. Since the introduction of the distant dial type of ampere-hour meter, the suggestion was made that the scales of all the electrical instruments carried on the vehicle, such as voltmeter, ammeter and ampere-hour meter, be combined in one case. This may be readily accomplished. A recent design, illustrated in Fig. 81, shows the distant dial and ammeter scales.

Compensated Meter for Lead Batteries. As explained in Chapter III., it is characteristic of lead batteries that the discharge capacity in ampere-hours varies with the discharge rate, the higher the latter the lower the capacity. For instance if the normal rate of a particular battery is 27 amperes for 5 hours the capacity being 135 ampere-hours, then at three times the normal rate experiment shows the capacity to be only 90 ampere-hours. In such an instance 45 ampere-hours would be lost, ostensibly, but such is not the case as in practice such an extremely high rate is not maintained for but very short periods, except under the most unusual circumstances. In going through sandy or heavy roads or climbing long hills the

current draw will be considerably increased and the capacity thus reduced. However, this is partly offset in practice by the short periods for which these overloads are borne and the ability of the battery to recuperate.

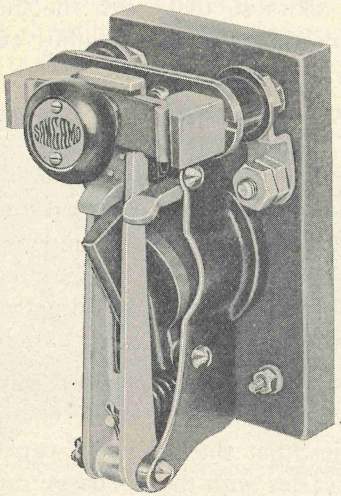


Fig. 82—Circuit Breaker.

From this explanation it may readily be understood that a compromise may be taken between theory and practice, so that the meter may be compensated so as to record faster on overloads, during discharge, giving a more accurate measure of the capacity available in the battery.

Installation and Connections. The ampere-hour meters, as furnished by the manufacturers are complete, ready for installation, which is a com

paratively simple matter requiring only the placing of the instrument in a convenient location where it may be easily visible, accessible for adjustment and resetting, and convenient for the wiring. When placed upon a dashboard which is inclined. the meter should be blocked so that the disc will ro-

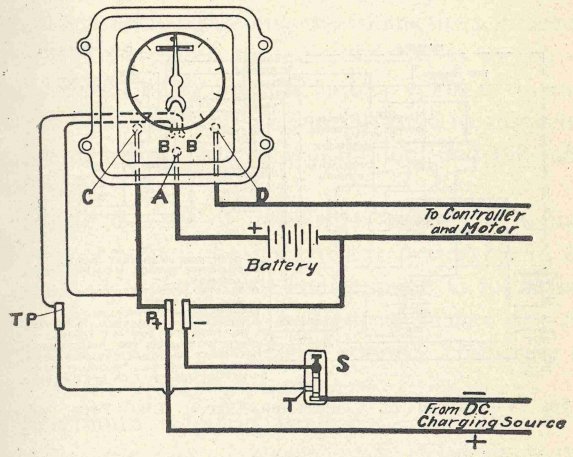


Fig. 83—Diagram of Connections for Differential Shunt Meter on Vehicle.

tate in a horizontal plane. If possible it is preferable to place the meter beneath the seat in order that it may be protected from the weather and the feet of the driver.

The wiring scheme is shown in Figs. 83 and 84, which illustrates the method of connecting the

charging plug, controller, battery and circuit breaker, Fig. 82, with the meter.

This diagram of connections, with modifications depending upon special wiring of the different makes of cars, can be generally applied. Care must be used in making the connection when the battery is divided for parallel operation during part

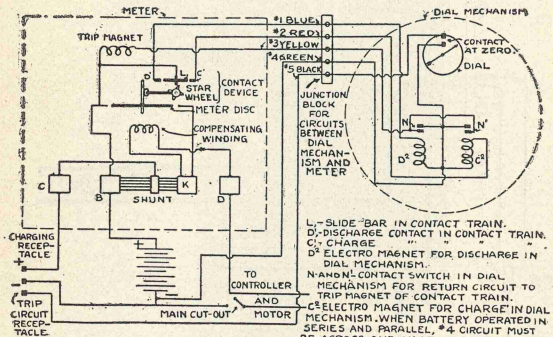


Fig. 84—Diagram of Connections Distant Dial Type Meter and Dial Mechanism.

of the time and operating in series on the higher speeds. When the cells are connected in parallel during discharge then the current from one branch only should pass through the meter and not the total current to the motor, because an erroneous reading would be thus obtained. For charging, of course the battery is connected in series, and all of the current passes through the meter in the

same manner as when the cells are all in series on discharge.

Inspection of all parts of the vehicle is necessary and the ampere-hour meter should not be neglected as it is very necessary to maintain all of the bolts, nuts, screws and contacts firm and secure so that loose contacts may not develop, causing heating or even burning of terminals. When new it would be well to go over the nuts and screws every two or three weeks, tightening the connections if necessary and thereafter approximately every month or two. When doing this the battery contacts, in fact all the electrical leads or wires, should be inspected to see that good contact is made and that the joint is secure.

Should damage of more than very slight nature be imposed upon the meter, it is preferable to remove it from the vehicle and return it to the manufacturer or competent instrument maker for repairs, rather than to submit it to the tampering of an inexperienced repair man.

Maximum Demand Indicator. In some communities the cost of electricity is based upon two items, the first being a charge for the readiness to serve, taking into account the highest point of demand during a predetermined period; the second takes notice only of the total amount consumed in the time indicated. The monthly consumption is measured by a watt-hour meter, while the maximum demand is derived by taking either a percentage of the total connected load of the installation, by the use of a Demand Indicator, or, in the case

of very large consumers, by measurement of the maximum load.

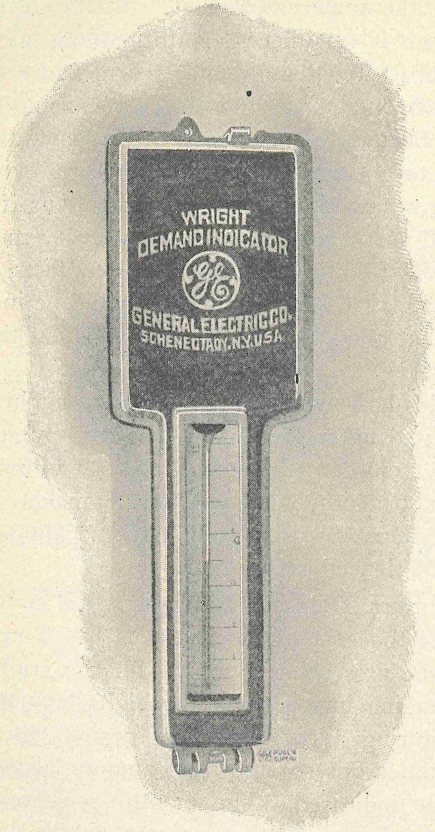


Fig. 85—Maximum Demand Indicator.

There are a variety of instruments used for the large installations but the recording of the maxi-

mum values of current for the smaller consumers is done by the indicators illustrated in Figs. 85, 86 and 87. In the Demand Indicator shown in Fig. 85, the flow of current in the circuit for a period of five minutes or more will cause the liquid in the index tube of this instrument to rise to a point opposite the scale of current. The liquid will remain at that point until it either is

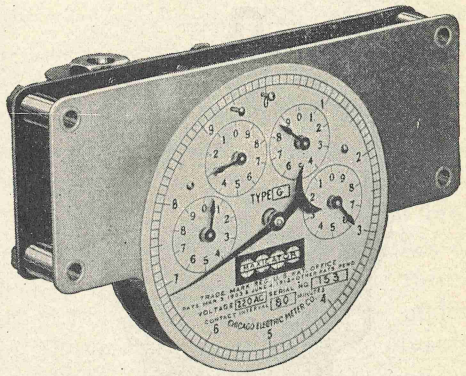


Fig. 86—Maximum Demand Indicator Attached to Watt-Hour Meter.

raised by the recording of a higher value of current or is reset.

Resetting is accomplished by tilting, allowing the liquid to return to the main liquid chambers. Frequently there are two scales, one of current in amperes and the other calibrated in kilowatt hours for the potential of the circuit, as 115 or 230 volts. In this manner the electricity meter and the Demand Indicator may be quickly read and reset by the au-

thorized meter reader and readily checked by the consumer.

The instrument shown in Fig. 87 is designed for use with a watt-hour meter, and prints on a tape the watt-hour consumption during the small time intervals also printed in adjacent position on the tape. This indicator may be used for either direct current or alternating current circuits.

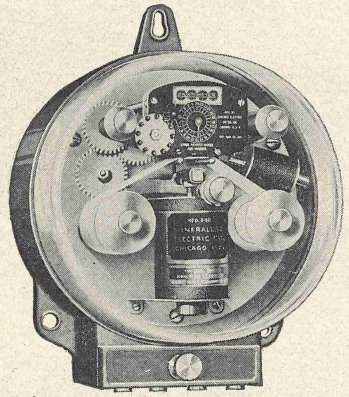


Fig. 87—Printing Attachment for Watt-Hour Meters.

The device illustrated in Fig. 86 takes the place of the watt-hour meter register, and also includes a large hand which indicates the maximum watt-hour consumption during half hour intervals. The mechanism is arranged so that, if the rate of consumption be less during succeeding intervals, the reading of the hand will not be altered, but if the rate at which the energy passing through the meter increases, then the hand will be moved to a position of greater demand. This device is applicable only to alternating current circuits, but modifications are provided so that the same principle may be used with direct current installations.

Watt-Hour Meter. The watt-hour meter records the electric power consumption, taking account of the current, the length of time for which it is used and the pressure or voltage at which it is supplied. The meter used for the purpose of measuring the electricity supplied in charging a storage battery does not differ from those installed for recording the consumption of light or power in factories or residences.

The external form of these meters is no doubt familiar to all. The internal construction, while interesting, cannot be explained within the scope of this book, but the readings of the dials deserve consideration at this point so that the methods of arriving at the cost of current may be understood.

The dials shown in Figs. 88 and 89 illustrate the meter readings. After noting the direction in which the pointers are moving, read the number on the dial that has been passed by the pointer, that is, the lower number. If there is doubt as to whether the pointer has passed the number or not, inspection of the next lower dial will determine. If the hand on it has started on a new revolution, then the pointer on the first dial has passed the doubtful number. The readings are recorded in kilowatt-hours, and the difference between two readings gives the number of kilowatt-hours consumed in the period intervening.

The cost of current for battery charging varies considerably in different parts of the country, depending upon the number of vehicles charged regularly, whether they are all charged at one time

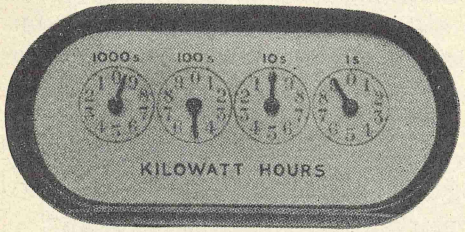


Fig. 88—Reading 9499 Kilowatt Hours.

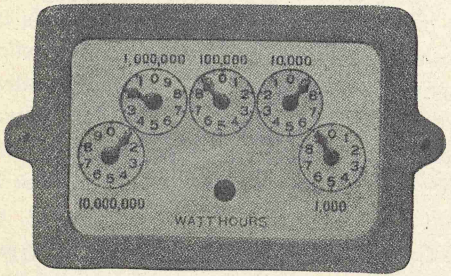


Fig. 89—Reading 1,188,900 Watt Hours.

or consecutively in sets, and also naturally upon the cost of producing and distributing electrical energy in the particular district. Owing to the fact that the vehicles are charged during the night when the residence and industrial loads are light, special rates

are usually extended in favor of this class of customers. Fortunately, this is profitable both to the central stations and the vehicles owners, since it provides off-peak load for the former and lower rates for the latter. The peak load refers to the periods of greatest demand on the power stations.

Remarks on the installation and maintenance of watt-hour meters are unnecessary in this connec-

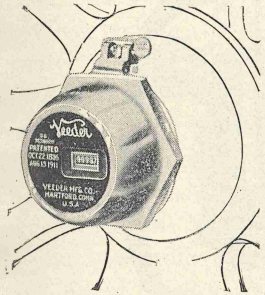


Fig. 90—Hub Odometer.

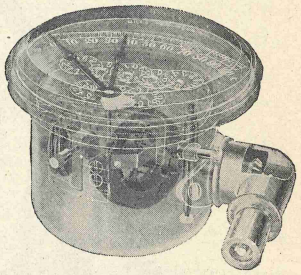


Fig. 91—Centrifugal Speedometer.

tion since they are installed and inspected periodically by the central station companies, excepting in such public garage installations as desire more detailed records for their own information. In such cases, arrangements can be made for competent supervision.

Mileage and Speed Indicators. In the operation of motor vehicles it is usually not only convenient and advisable, but very often necessary, to know the speed and distance characteristics of the vehicle. In the measurement of distance and speed, including the variation of the latter, many devices are used and they may be divided into two classes,

namely, those which give the instantaneous readings of speed and those which record its variations over a predetermined period.

Fundamental quantities involved are time and distance. Time is measured by a clockwork of the familiar type, while distance alone is measured by

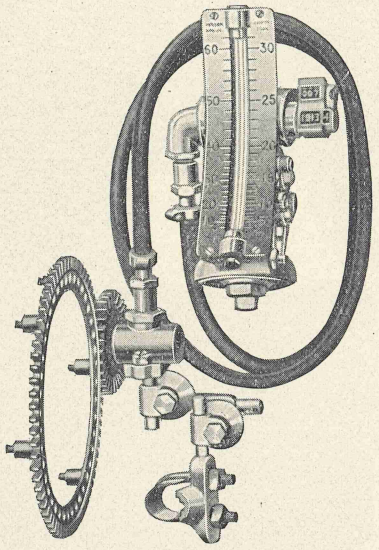


Fig. 92—Tachodometer.

a type of odometer. The odometer is usually geared directly to one of the forward wheels of the vehicle although, when combined with a speedometer, the device is generally placed within the car or upon the dashboard for easy reading and actuated by a flexible shaft from the wheel. The sim-

plest type of odometer is that which is placed upon the wheel itself, Fig. 90, and consists of several small toothed wheels and a recording train showing the actual mileage for the size of wheel to which it is geared.

The speedometers are of four general classes, the centrifugal, hydraulic, magnetic and electric.

The centrifugal speedometers are among the most widely used and depend upon the action of a revolving weight against a spring, Fig. 91. The greater the speed of rotation of the weight, the more intense is its effect upon the stationary spring, so that a pointer attached to the latter will be revolved over a graduated scale or dial face. Any changes in speed are quickly taken up by the sensitive instrument and indicated by the pointer.

The hydraulic speedometer consists in the use of a liquid, such as oil, in a tube or chamber containing a small paddle wheel. The flexible shaft from the road wheel is geared to this small paddle wheel, which sets the oil in motion, propelling it to a height in the tube proportional to the speed of the paddle, that is, to the speed of the car. The illustration, Fig. 92, shows this instrument ready for installation.

The magnetic speedometers, Fig. 93, are also very extensively used. They depend upon the magnetic attraction between a revolved magnetic core and an attracted aluminum cup carrying the indicated speed digits. The attraction between these two, balanced against a spring of special temper, makes the indication in the window of the instru-

ment, at which the numbers appear, dependent upon the speed of the flexible shaft or, in other words, upon the speed of the car.

When it is required to record mileage as well as to indicate the speed, a small recording train is also actuated by the flexible shaft within the speedometer case.

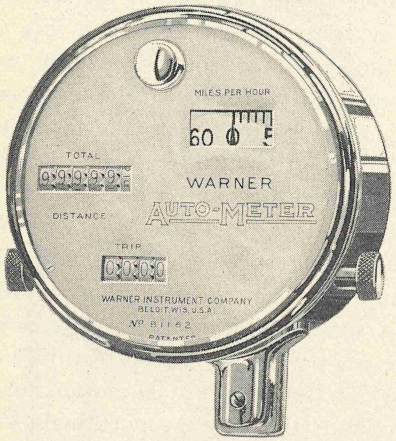


Fig. 93—Magnetic Speedometer.

The electric speedometer or tachometer consists of a small electric generator driven from the wheel of the vehicle and connected by two thin wires or leads to the indicating instrument, which may be located in a convenient part of the car. The indicating instrument is in reality a voltmeter calibrated, that is, its scale is graduated in miles per hour instead of volts. Ordinarily this type of in-

strument is very little used in vehicle application and does not include a mileage recording device.

Frequently it is very convenient and advisable to know the exact slope or grade of a hill, and for that reason an instrument, known as a gradometer, may be attached to the car or secured as a unit with

Fig. 94—Recording Speedometer.

some makes of speedometers. This gradometer is simply a liquid in a tube with a scale marked in per cent. grade. It is very similar to the carpenter's level in which the bubble under the centre mark shows that the work is true.

The devices mentioned in the preceding paragraphs are very extensively used, both on commercial and passenger vehicles, and it is safe to say that there is a negligible per cent. of the total number of vehicles in use which are not equipped with one or more of these instruments. Meters which

give a permanent record of the relative speeds and distances travelled are not used so widely, however, having particular application in commercial service, where the motion of the truck throughout the working day is a very important item in the operation of

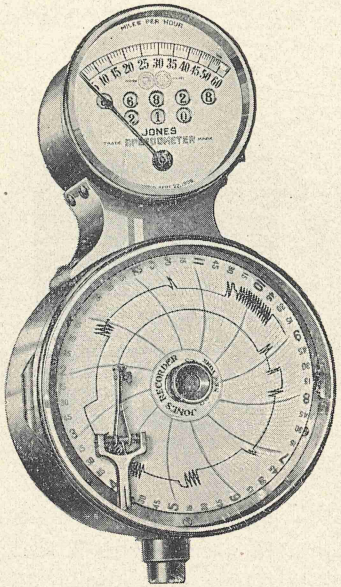


Fig. 95—Travel Recorder.

the business. In order to place a check upon such operations and to secure data from which calculations may be made, several types of recording devices have been introduced which differ somewhat in construction and principle. The most complete shows upon a chart or tape the standing time, the time consumed in motion, and the speeds at which

the truck is operated. From such a record it is possible for the delivery superintendent or supervisor of the vehicle service to inspect the movements of all the trucks throughout each day, and to plan or devise methods for increasing their efficiency, either by changing the loading, the drivers

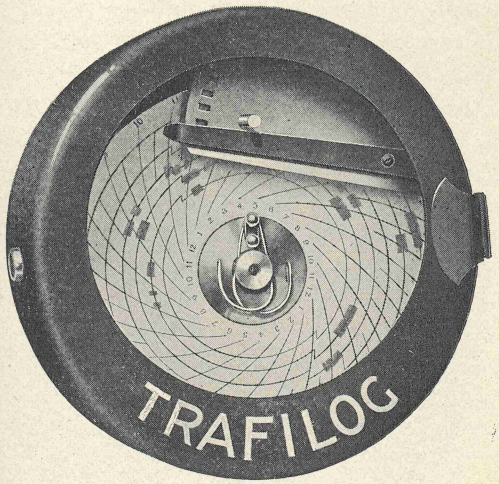


Fig. 96—Traffic Recorder.

or rearranging the routing. In many cases very complete records of this nature would leave nothing to be desired toward increased efficiency, but such a condition could not be assured unless means were taken to find out the details which could only otherwise be determined by the continuous services of trained and skillful observers. Figs. 94, 95 and 96 show several of these recording instruments

with the charts and tapes used for preserving the records.

A form of recording device which is very widely and popularly known in the large cities is the taximeter, which is a form of traffic recorder arranged to show its record in dollars and cents as well as in miles. These devices are well known and need no particular comment at this point.

The care of these speed indicating and recording instruments consists in keeping them clean and as free from dirt and injury as possible. The exposed wearing parts, such as the gear and flexible shaft pinion upon the wheel, should be inspected frequently and kept free from mud, and oiled or greased moderately. The instruments proper are so protected in their cases that practically no attention is necessary. When they are taken apart for repair, oiling, etc., these operations had best be done by an expert so that the delicate mechanism may not be disarranged.

CHAPTER VIII.

WHEELS, RIMS AND TIRES; THEIR CARE.

The subject matter dealing with the very important parts of the automobile designated by the names of wheel, rim and tire might well occupy a complete volume. In fact, several volumes would not be sure to do the subject justice. For the purposes of this book it will be considered sufficient if the principles are explained and the points, which make for the most satisfactory service, emphasized. This subject has received considerable attention since the advent of the gasoline motor car and it probably will serve our purpose best if the features

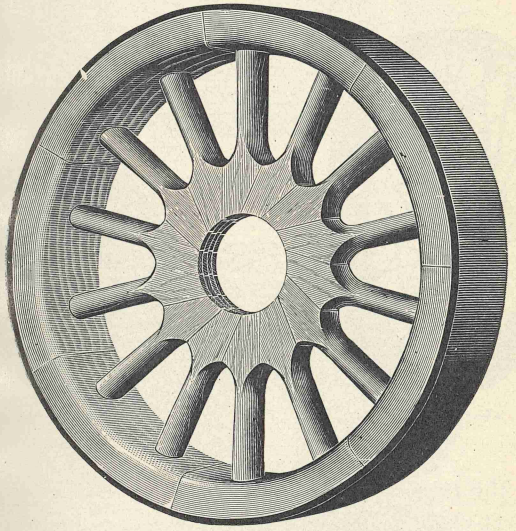


Fig. 97—Artillery Wheel.

most characteristic of electric vehicle practice are brought forward.

The wooden artillery wheel shown in Fig. 97 is practically universally used on all motor vehicles. The artillery wheel is very satisfactory inasmuch as the second growth hickory used in its construction combines the features of strength and resistance to shocks with light weight.

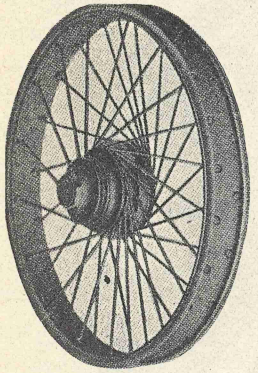


Fig. 98—Wire Wheel.

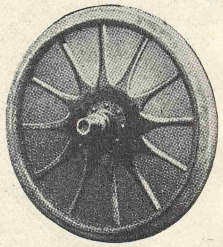


Fig. 99—Metal Wheel.

In the past few years the reduction in the supply of first-class wood has made the introduction of the wire wheel more rapid, especially in Europe where the scarcity is more pronounced than in this country. Wire wheels (Fig. 98) are lighter than wooden wheels and the claim is made that they permit greater tire life by rapidly radiating the heat generated by tire friction. Inasmuch as the rim of a wire wheel is lighter than the felloe and

rim of the artillery wheel there is less flywheel effect and starting and stopping may be accomplished

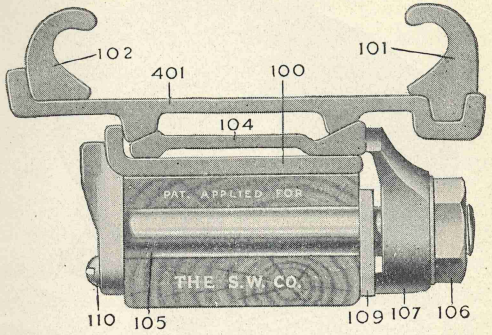


Fig. 100—Demountable Rim.

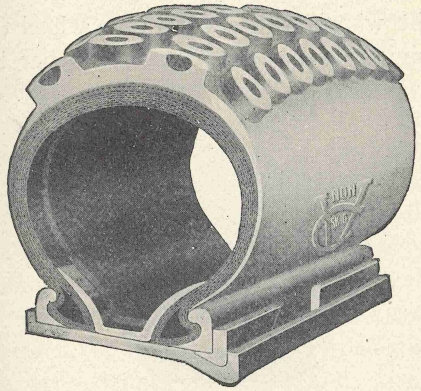


Fig. 101A—Quick Detachable Rim, Clincher Type.

with less time and energy. An essential difference between wire and wood wheels is in the manner in

which the load is carried. In the wooden wheel the weight is carried by the spokes in the lower

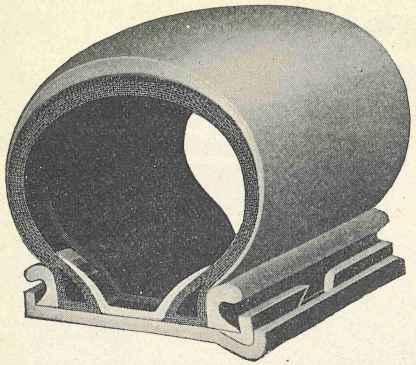


Fig. 101B—Q. D. Rim, Straight Side Type.

half of the wheel, while in the wire wheel the hub and housing is suspended from the upper half of

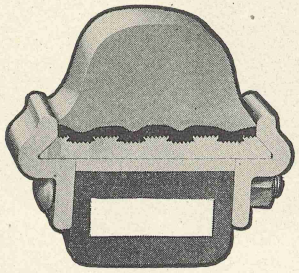


Fig. 102—Cross-section of Truck Tire.

the rim by the spokes in tension. For this reason it is said that shocks are absorbed more readily and that greater life may be secured from tires.

Metal wheels (Fig. 99) formed by the use of two steel discs, suitably held by the hub and rim, are being used in trucking service for special purposes, such as enclosing motors or gearing in the wheel proper. The manufacturers claim strength and resistance to side-thrusts combined with lightness as their features and practice appears to verify the statements.

Rims. The rim is essentially a steel band designed to rigidly hold the tire and permit of its ready application or removal. The rim either encircles the wheel felloe or is secured to a band which does. If the felloe band and rim are separate then it is said to be a demountable rim (Fig. 100). A locking device, of screws, bolts or clamps, designed to hold the rim rigidly in position yet easy of removal, is a necessary part of a demountable rim.

The shape of the rim section as shown in (Fig. 101A) determines the type of tire to be used. For pneumatic tires the rims are known as (A) clincher or (B) straight side. These names are descriptive of the method employed in securing the tire to the rim. The hooks of the clincher rim engage with the hooked beads of the clincher tire so that when inflated there is small possibility of the tire coming off. In fact, the trouble, is, that when the tire has been on for a length of time and is firmly seated by rusting or otherwise, there is difficulty in removing it for repair or renewal. To obviate this difficulty, which is most marked with the larger sizes of tires, the outside hook flange is made as a

removable ring held in place by a locking ring. This construction is known as a quick detachable rim. Instead of the clincher tire, a straight side tire is often used so that instead of the hooks of the removable ring being curved inward as with the clincher tire, they are reversed, curving outward.

For solid or cushion tires, construction of the same style, but with greater regard for sturdiness,

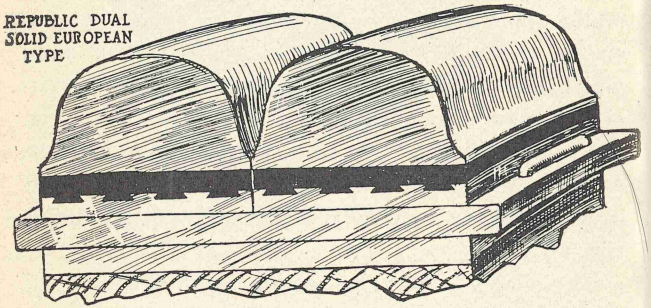


Fig. 103—Pressed on Tire.

is made use of as shown in the accompanying illustration (Fig. 102). The earlier forms of solid tire (Fig. 103) were forced onto the rim by a press and locked in position. Obviously, it was necessary to remove the wheel in order to effect repairs or renewal. This led to the introduction of demountable types for those whose service required easy and quick removal.

Many of the dimensions of the wheels and rims most commonly used have been standardized by the Society of Automobile Engineers, so that tires

of any make whatsoever may be used interchangeably on a standard rim.

Rubber tires may be readily classified as pneumatic, cushion and solid. These, as well as wood and steel tires, are very familiar forms to all motorists and it is probably this very familiarity which breeds a contempt for their care. As the use of wood and steel tires are not recommended for electric vehicle service, except trailers, the following paragraphs will be confined to the construction and care of rubber tires.

The pneumatic tire is a combination of rubber compound and cotton fabric, so proportioned and interwoven that the complete unit may not only confine the air for cushioning but also withstand the wear and tear of hard use. Resiliency makes demands which cannot wholly be satisfied if endurance is kept in mind so that, a compromise must be effected giving the required cushioning with the least sacrifice of elasticity.

The modern efficient electric vehicle has been developed from the earliest type, not by radical changes, but by the refinement of the parts; by the reduction of waste power to a minimum. At first, tires were used which had satisfactory wearing qualities, but being hard, made it necessary to lift the weight of the car over every obstruction and out of every small crevice. As this took energy, means were found to design a tire which absorbed these inequalities of road surface of its own accord. The battery, therefore, having a definite capacity, could utilize it to propelling the vehicle

forward instead of lifting it over thousands of small obstructions. This improvement is specifically due to the use of more elastic compound and a different weave of fabric. At first strength was sacrificed for this efficiency but today after years of experiments and steady service, tires are giving not only efficient mileage per charge of battery but also long life.

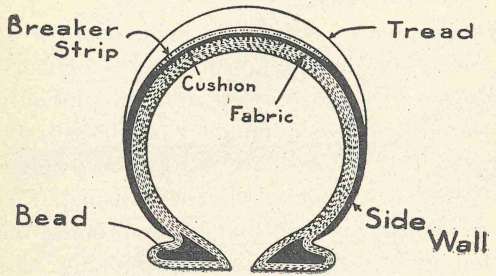


Fig. 104—Cross-section, Indicating Parts of Tire.

This point is important, and although lower first cost may seem to justify the use of less efficient tires, a moment's thought should be sufficient to emphasize the additive loss during months, resulting from their use. In the case of the gasoline motor vehicle this refinement in tires is not so necessary since the continued supply of energy depends upon the size of the gasoline tank. With the electric, however, the charge in the battery is fixed and it is not a matter of how much more gasoline, but

what reduction in mileage. The question of tire efficiency applies to cushion and solid rubber tires as well as to pneumatic tires.

The essential parts of the pneumatic tire are shown in (Fig. 104) illustrating the regular clincher type. The parts are known as tread, breaker strip, side walls, cushion, fabric and bead and meet the following uses.

The tread is the portion of rubber compound which is in direct contact with the road surface and of all parts is most subject to wear. It must resist wear due to the weight of the vehicle and in the case of rear tires, due also to the strain of traction. On good smooth roads this is not excessive but becomes quite a feature in slippery places where the wheels may slip and spin, bringing gashes and cuts into the material. While it is advisable to have the tread thick from the standpoint of good wearing qualities, resiliency and weight are items which must be considered in the choice for most efficient results. Careful study and exhaustive experiments have lead the manufacturers to their conclusions in the production of a suitable tread.

The breaker strip immediately beneath the tread is used to receive and distribute the force of the shocks over a wider surface. It, as well as the other fabric parts of the tire, is made of specially treated cotton. The walls on the side of the tire are made of alternate layers of fabric and rubber so that sufficient strength will be given to resist the bursting stress of the air within and yet be sufficiently resilient to do the greater part of

stretching in the operation of rolling. The cushion shown between the breaker strip and inner fabric

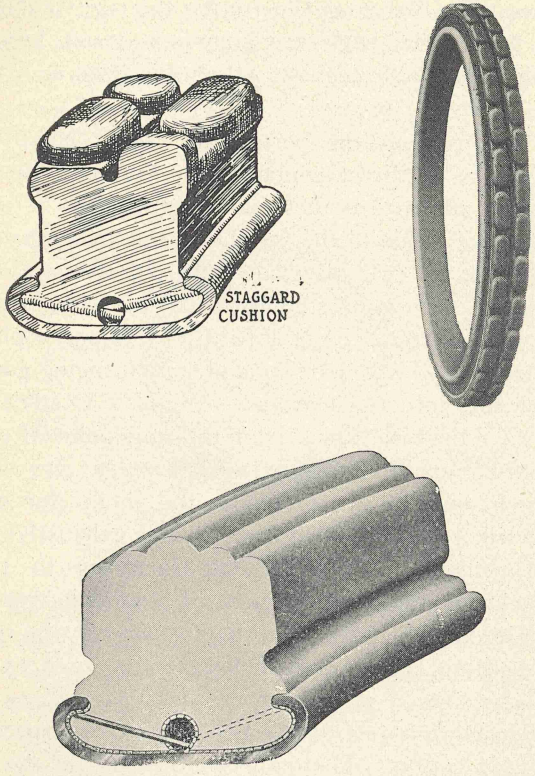


Fig. 105—Cushion Tires.

is of very resilient rubber and is an additional factor in shock absorption. The fabric is usually

made of what is known as combed Sea Island cotton "frictioned" or pressed between and impregnated with fine Para rubber. The fabric gives the

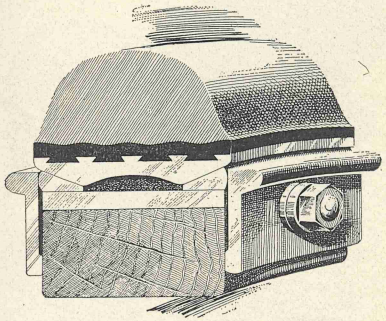


Fig. 106—Solid Tire, Clincher Type.

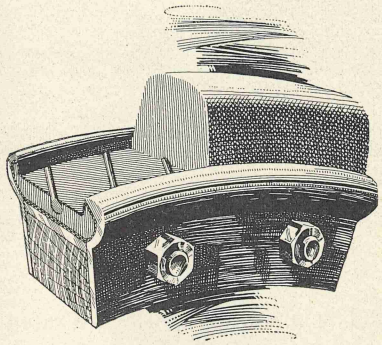


Fig. 107—Solid Tire, Demountable.

strength to the tire, is protected and the layers combined into a unit by means of the rubber. During the building up process, when layer after layer

is added, the parts are formed gradually into a finished unit by the "curing" or heating process and finally the completed tire is vulcanized into finished shape.

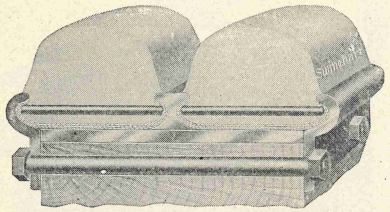


Fig. 108—Dual Tires, with Crosswires.

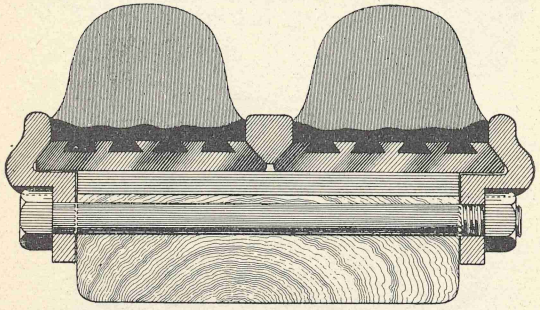


Fig. 109—Demountable Wireless Tires.

The bead is made of fabric saturated with rubber and pressed into the desired shape. It may contain material such as steel wires or hardened rubber in order that it may be firmly secured to the rim when inflated and yet be readily removed for repair or removal.

The cushion tires used are of the forms shown in (Fig. 105). The object sought is to obtain

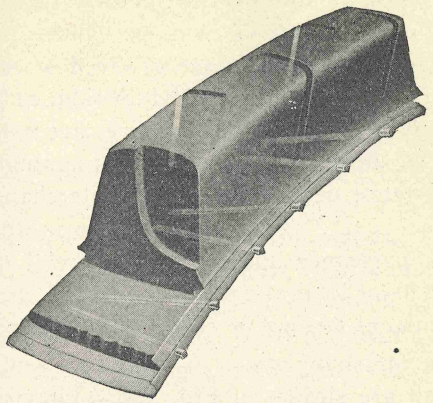


Fig. 110—Cross-section of Electric Truck Tire.

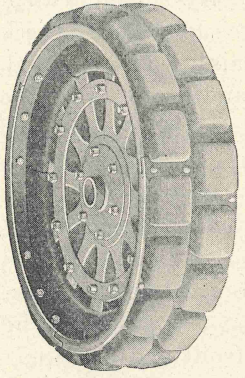


Fig. 111—Sectional Block Tire (Dual).

freedom from punctures, blow-outs, etc., secured in the solid tire together with the resiliency ob-

tained from the pneumatic tire. This is accomplished by proportioning the quantity of rubber in the compound and by the method of arranging the supporting ribs or bridges. The surfaces of the tread in some cases are grooved or cupped in order that firm traction and avoidance of skidding may be secured. These tires are held to the rim in a similar manner to the pneumatic tires and the latest designs allows for interchangeability with the latter. This form of tire is applicable both to passenger and light commercial cars, the conditions of load and speed being the governing specifications as may be readily understood.

There are many styles of solid tire, some forms of which are shown in Fig. 106. They differ in the method of attaching to the rim, either being secured by simply a clincher rim or fitted with transverse wires held under the hooks of the rim flange or containing longitudinal wires either at the center, near the rim or at the side. Another method of holding the rubber firmly to the base is by making the base of metal dovetailed to hold a hard rubber sub-base and vulcanizing the tire to it. This practice is applicable for the largest tires and is shown in Fig. 109.

Tires may be arranged either single or dual, depending upon the weight to be carried, generally single in front and dual on the rear wheels, as 60% of the normal load may be considered as supported on the latter.

A type of solid tire which meets the requirements of heavy vehicle service is the "sectional

block tire." (Fig. 111.) The advantages claimed for this style are greater life, greater resiliency and less cost of renewal, as the sections may be replaced individually, not necessitating the application of a complete tire when the damage extends to but a limited portion.

CARE OF TIRES.

Whether the tire be used in passenger or commercial service, the desire to secure continuous service with the least delay and expense is common. Although the pneumatic tire is most vulnerable, yet there are precautions which apply to all rubber tires because they are rubber, and therefore susceptible to the abuses which rubber will not withstand.

Elasticity is a characteristic of many substances, but the bare mention of the word brings to our minds the ability of rubber to suffer distortion and return to its original shape. Yet rubber, like steel, when strained beyond its elastic limit, will not return to shape. The fibres or small particles possess the ability to hold together and resist motion, but when their resistance has been exceeded they are permanently separated and their power of cohesion is lost. In other words, the material is said to be overloaded. Apply this explanation to a rubber band which we stretch, or a rubber tire which we compress, it is evident that the results are the same. A tire of a given size is designed and recommended after tests to carry a given load indefinitely. It is not reasonable to expect it to carry twice or three

times the load continuously, yet unconsciously a large number of users continually overload their tires and are at a loss to understand their early failure.

When the tires are installed to carry full load distributed over the vehicle, it is evident that piling it upon the rear end for easy removal by a lazy driver exerts unnecessary strain on the tires. Considerable overhang produces a powerful crushing leverage amounting in effect to a heavy overload. When it is possible to unload a truck should not be allowed to stand over night fully loaded.

Overspeeding is responsible for many accidents and casualties and is to be heartily discouraged from every standpoint. In this connection it is well to consider the blows to which the tire is subjected when striking an obstacle at high speed. As a rule the maximum speed of the electric vehicle lies within the range dictated by safety and economy, so that difficulty from this source is reduced to a minimum.

When passing over railroad tracks or ruts care should be exercised so that the blow may be as small as possible. Similarly, in backing against a curbstone, it should not be used as a stop placed there for the convenience of the driver.

The deterioration produced by the several forms of abuse known as overloading may not be even visible to the eye, but the results will in time show up and the failure be unjustly laid to faulty material or poor workmanship. It

has been estimated that 5% excess weight added to the vehicle imposes an overload of 15% in wear and tear on tires. The salvation is in prevention alone. Tires which are too large, "oversize," are a profitable investment in the long run over a scant equipment. The following tables are appended representing safe load capacities:

TABLE NO. 10.

GRADUATED TABLE OF SOLID TIRE CARRYING WEIGHTS

Cross Section.	Diameters 32" lbs.	34" lbs.	36" lbs.	38" lbs.	40" lbs.	42" lbs.	mph.
2" Singles	450	475	500	525	550	575	20
2.5" "	670	710	750	790	830	870	20
3" "	900	950	1,000	1,050	1,100	1,150	20
3.5" "	1,130	1,190	1,250	1,310	1,370	1,430	18
4" "	1,350	1,425	1,500	1,575	1,650	1,725	16
5" "	1,800	1,900	2,000	2,100	2,200	2,300	14
6" "	2,250	2,375	2,500	2,625	2,750	2,875	12
7" "	2,700	2,850	3,000	3,150	3,300	3,450	10
2" Dual	1,125	1,188	1,250	1,312	1,375	1,438	18
2.5" "	1,675	1,775	1,875	1,975	2,075	2,175	18
3" "	2,250	2,375	2,500	2,625	2,750	2,875	16
3.5" "	2,825	8,975	3,125	3,275	3,425	3,575	14
4" "	3,375	3,560	3,750	3,940	4,125	4,310	13
5" "	4,500	4,750	5,000	5,250	5,500	5,750	12
6" "	5,625	5,940	6,250	6,565	6,875	7,190	10
7" "	6,750	7,125	7,500	7,875	8,250	8,625	10

TABLE NO. 11.

GRADUATED TABLE OF PNEUMATIC TIRE CARRYING WEIGHTS

Size, inches.	Rear, lbs.	Front, lbs.	Size, inches.	Rear, lbs.	Front, lbs.
28 x 3	350	425	40 x 4	850	1,000
30 x 3	375	450	42 x 4	900	1,050
32 x 3	375	450	32 x 4½	1,100	1,100
34 x 3	400	500	34 x 4½	900	1,125
30 x 3½	450	550	36 x 4½	1,000	1,250
32 x 3½	500	625	42 x 4½	1,200	1,450
34 x 3½	550	675	34 x 5	1,000	1,250
36 x 3½	600	700	35 x 5	1,000	1,250
30 x 4	625	750	36 x 5	1,000	1,375
32 x 4	650	800	37 x 5	1,100	1,350
34 x 4	700	875	38 x 5½	1,350	1,600
36 x 4	750	900			

ALIGNMENT.

It frequently happens that a glancing blow against a curbstone or road shock causing bent axles or wrenched steering knuckles takes the wheels out of true. When thus out of alignment, the tire not alone rolls, but turns in another plane,

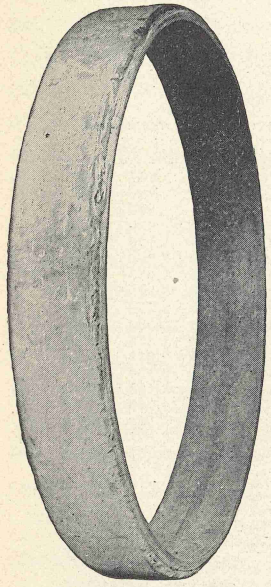


Fig. 112—Wheels Out of Alignment.

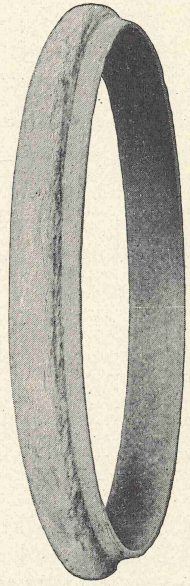


Fig. 113—Running in Car Tracks.

so that, besides requiring more energy for propulsion, the tread of the tire is ground off as surely as if it were held against a grindstone. (Fig. 112.) Accidents of this nature should be remedied at the earliest opportunity by properly aligning the wheels. If the distance between the rims of the two front or rear wheels is the same at front and rear points, then the alignment is correct.

OIL AND GREASE.

Oils and grease in their proper place are very important factors in maintaining smooth operation, but when applied to rubber tires, the result is the ruin of the tire. The compound is attacked and reduced to the consistency of mush losing its resiliency and resistance. The garage floor should be kept free of oil and the tires kept clear of puddles of oil if they are present. Gasoline may be used to remove oils or grease from the tires, as it dries very quickly.

ABRASION.

There are very many ways in which the rubber may be worn off the tread or sides of the tire. Among these may be mentioned tires out of alignment, cuts from new roads of broken stone, car tracks and scraping against curbstones. Running with the tires out of alignment wears the tread very rapidly, as has been described.

Small cuts from litter or from sharp stones are not serious in themselves, but when neglected, dirt and sand work their way in, making the cut larger, and injuring a considerable portion of the tire. In the case of pneumatic tires, the sand works its way in between the rubber and the fabric, and with the help of moisture weakening the piles, a "blow-out" results. The small cut should be repaired at the earliest opportunity by vulcanizing as explained on (Page 252).

Running in street car tracks (Fig. 113) and against the curbing are very similar. The sharp edges of the rail flange cut small pieces off of the sides of the tire and in some cases, such as running over a frog which has been worn to a knife edge, leave big gashes which spell disaster. Granted that it is a big temptation to ride in the trolley tracks rather than bounce over cobbles or Belgian block pavements, yet it should not be

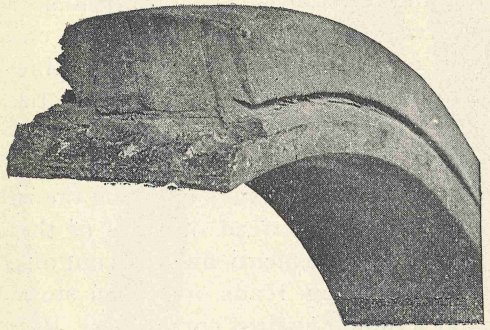


Fig. 114—Caused by Overloading.

indulged in except with the understanding that it is very damaging to the tire. In wet weather the effects are most pronounced, as rubber may be cut very much more readily when wet than dry. Small tires naturally sink deeper into the rail channel and thus have their sides worn away more rapidly than larger tires, which sustain the damage on the tread.

Starting and stopping give ample opportunity for excessive wear. There is probably no one

with the least observing turn of mind who has not seen cars started from rest with a jump to run off at high speed. Such action causes a severe strain upon the tire and its fastenings, and really

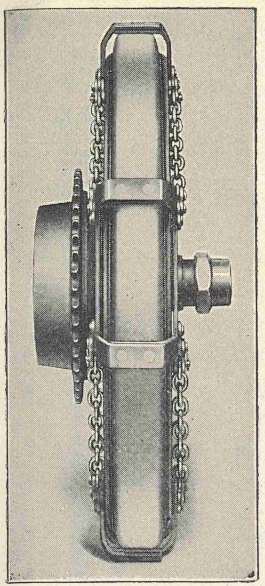


Fig. 115—Anti-Skid Tire Grips.

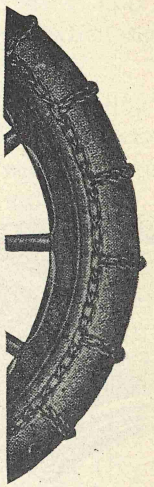


Fig. 116—Anti-Skid Chains.

is a form of overloading the elasticity of the rubber. With heavy loads there is a great tendency to tear the rubber and fabric from its anchorage. Easy acceleration will do much to prevent injury from this cause.

Likewise, who is there who has not seen a driver slam on his brakes and bring the car to a grinding stop? No motorist in his sane moments

would think of holding his tire against a grindstone, yet those who suddenly apply the brakes and slide the locked wheels over the road surface, are guilty of exactly that offense. Yes, there are emergencies when danger of accident may even

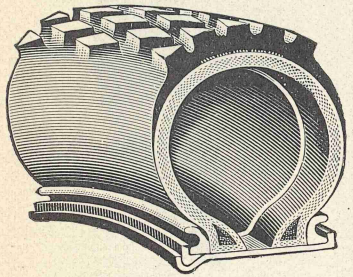


Fig. 117—Section Non-Skid Tire.

Fig. 118—Tire Gauge.

make reversing the driving mechanism necessary, but those instances are usually far and few between, and our arraignment of the thoughtless ones is just. The vehicle should be gradually brought to a standstill by slowly increasing the brake pressure.

While speaking of brakes, it is well to remember that the braking should not only be gradual,

but that it should be equal upon each wheel and tire.

Adjustments are provided so that the pressure may be equal upon each wheel and periodic inspection should be given to this important item. When one wheel stops the car then the entire grinding action is borne by the tire of that wheel, being double the wear sustained when the slide takes place on both tires.

Skidding. Skidding, or the uncontrolled movement of the rear wheels on wet pavements in a lateral direction, is very often caused by unequal brake adjustment. Also, the momentum of the vehicle, tending to continue in its original path, after the front wheels have been turned, is accountable for this dangerous action. When possible, the front wheels should be turned in the direction in which the car is sliding, in order to counteract its effects.

Several means have been introduced, such as tire chains, grips and special treads (Figs. 115, 116) for the purpose of reducing skidding and securing better traction on wet or oily roads. Tire chains are effective and extensively used with satisfaction. They should be loose enough to slide around the tire so that the cross links may give traction to the entire tread instead of confining it to a limited number of points. For this reason it is better to have a considerable number of cross bars so that the blows as the tire grips the road may be increased in number, but decreased in magnitude. While indispensable for driving in

congested traffic or slippery roads, they should be removed when the road conditions do not make them necessary. Under no condition should they

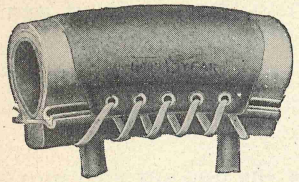


Fig. 119—Tire Bandage.

Fig. 120—Inner Tube Protector.

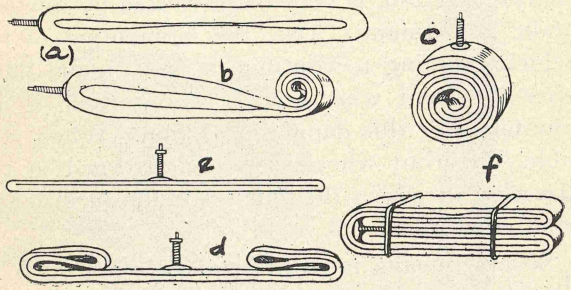


Fig. 121—Folding Inner Tube for Storage.

be fastened permanently to a spot on the tire, as it would direct the entire driving strain to the small section thus confined, severely overloading its elasticity and resiliency. Finally, if the links have been worn sharp they should be replaced, as the sharp corners cut into the rubber of the tread.

At present there are many special anti-skid treads recommended by the different manufacturers, which have the one aim in view. The principle used is to effect the formation of a vacuum

when there is a tendency to lateral movement. This is accomplished either by cups, small blocks or projections from the tread of many varieties of shape and kind. (Fig. 117.)

The question of routing has a decided effect on the wear of tires, so that whenever possible poor roads should be avoided or a detour made, as prevention is far better in most all cases than the cure. This is a very simple matter with passenger cars, but naturally might lead to complications with commercial vehicles. Having in mind the probable damage, however, means may usually be found to avoid stretches of sharp broken stone, deep ruts, etc.

Standing Idle. It is only natural to expect the rubber of the tire to acquire a permanent set or become flattened under several thousand pounds pressure. To avoid such strain vehicles should be jacked up and supported on horses (which may be very inexpensively constructed) when standing idle for any length of time. Heavily loaded vehicles should be relieved of their load when standing over night. With pneumatic tires not only is it necessary for the casings to withstand the pressure of the air within, but the weight of the vehicle, so that the importance of these simple means of relieving unnecessary strain should be evident to all.

CARE OF PNEUMATIC TIRES.

The most important thing to remember in the use of Pneumatic Tires is to keep them well supplied with air. It has been estimated that over

three-quarters of the difficulties encountered by motorists are due primarily to lack of inflation. It is necessary to inflate the tire to the proper pressure specified by the tire manufacturer and given in able No. 12 below and keep it at that

TABLE NO. 12

PRESSURE OF AIR IN PNEUMATIC TIRES.

Size inches.	Pressure Lbs. per sq. in.
2½	45
3	50
3½	60
4	70
4½	80
5	90

pressure as long as the tire is in use. There are remarkably few cases of over inflation except where air compressors are carelessly or ignorantly used. There is little doubt of the fact, however, that with a hand-pump, not over one man in a million has ever put too much air into his tire.

There is but one safe way to govern the inflation of tires and that is to purchase a reliable tire gauge and use it regularly for inspection and when inflating. It is impossible to tell by looking at the tire, kicking it or counting the number of strokes of the pump just what the pressure is. There is only one reliable means and that is the gauge (Fig. 118), which is inexpensive and certainly pays for itself many times over in tire savings.

An erroneous impression which seems to have received wide circulation is the idea that in hot

weather tires should not be inflated to their standard pressure. Although the pressure in the tire is not wholly independent of temperature, yet the variation is so slight that it may be neglected for all ordinary conditions.

The pneumatic tire being constructed of rubber compound and cotton fabric, is intended to be possessed of strength to withstand the pressure from within, shocks from without, and offer resilience in motion. The side walls of the tire are subjected to a bending motion which is very pronounced and continuous when the tire is run soft or semi-deflated. This alternating bending produces heat just as the bending back and forth of a piece of wire makes the latter so hot that it cannot be comfortably held by the fingers. The heat thus generated in the threads of the fabric extends to the other parts of the tire and produces gradual deterioration. There are other forms of friction within the tire which generate heat which cannot be so easily avoided as the one just explained. The fabric within thus weakened may be readily broken by a severe shock or bruise and if not repaired will result in a "blow-out."

Smaller cuts in the tread or side walls may be readily encountered and if not remedied at once gradually increase in size, causing more serious damage. Sand or dirt may easily work their way into the small cut, making it larger and finding a place between the rubber of the tread and the fabric make the gap larger and form a "sand blis-

ter" or "mud boil." These blisters continue to increase in size and speed, allowing water to find its way to the fabric. Cotton fabric is very strong when dry, but when exposed to dampness or moisture it rapidly loses its strength. It can be easily understood, therefore, that when a small cut is allowed to develop and water is permitted to attack the fabric, that a sharp shock to the material at the damaged point will cause it to give way and allow air to escape, in many cases ruining both the tube and the casing.

Another source of injury to the casing is the severe blow encountered at high speed. Although no evidence may be left on the outside of the casing and no trace of damage be found until a blow-out occurs, it may generally be assumed that the innermost ply of the fabric is broken. Gradually the plies above it having to endure greater strain, give way until the entire thickness of fabric is destroyed, and finally a blow at the damaged point causes a blow-out.

Under normal conditions of service the tread is gradually worn off and unless damaged by cuts will not need repairing until it is worn almost to the fabric. Obviously it should be retreaded before such a point is reached in order that the fabric may not be damaged either by being ground off or subjected to moisture.

Small cuts, as noted above, should receive immediate treatment by being cleansed of sand and dirt with gasoline or benzine. The sides and the space about one-half to three-quarters of an inch

around the sides should be roughened by rubbing with sandpaper, the cut filled with patching cement, an application of rubber gum should then be worked into the cut and allowed to set for

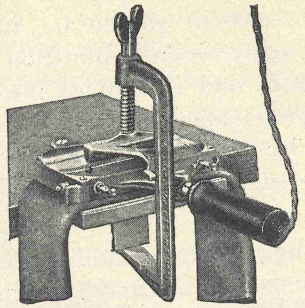


Fig. 122—Electric Tube Vulcanizer.

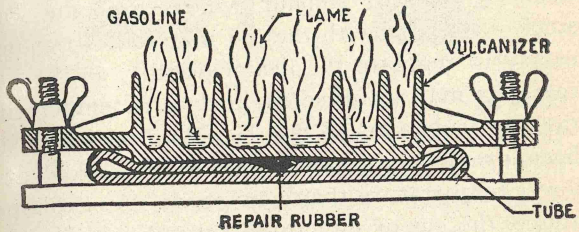


Fig. 123—Gasoline Tube Vulcanizer.

several hours before using the tire. This treatment will suffice for small cuts, but with larger ones vulcanizing should be resorted to.

In the treatment of sand blisters or mud boils, they should be opened and the rubber cut away so

that all dirt and foreign material may be removed from between the rubber and the fabric. After cleansing thoroughly with gasoline, the good tire surface around the edge of the cut should be roughened and several applications of cement given. The cement should be allowed to dry thoroughly before each application and the rubber gum added and vulcanized into place. Vulcanizing may be done either by the acid cure vulcanizer or by one of the mechanical types of vulcanizers such as those heated by gasoline, steam or electricity (Figs. 122-125).

Vulcanizing. Uncured rubber stock is used as a filler in replacing the material which has been cut out of the tire or removed by a blow-out. The vulcanizing cement is different from that used in making ordinary repairs, in that it contains a small amount of sulphur which cures the Para stock integrally with the old material. It is necessary to regulate the heat carefully, as the vulcanizing may be effected best at a temperature ranging from 250° to 275° F. Material which has been previously treated should be worked at a lower temperature than new stock. As explained above, the cut or punctured tube should be thoroughly cleansed and roughened with sand paper, after which two coats of the vulcanizing cement may be applied, allowing the first to dry before the application of the second. Strips of rubber are then cut to fit into the opening and a piece of cloth applied between the face of the vulcanizer and the rubber. This treatment of from fifteen

to twenty minutes at the proper temperature will effect the repair of any ordinary damage. Should the cut be very deep it may be necessary to fit in several layers of rubber, all of which may be vulcanized in one treatment.

Acid Cure. In applying a patch with the acid cure outfit it is also important to clean the surface thoroughly and when the acid has been worked over the cement, the patch should be rapidly placed in position and smoothed down forcing out all air bubbles and if possible clamped tightly to dry. In making repairs by patching, the proper time to apply the patch, which also must be prepared with cement, is when the second coat has become "tacky," that is almost dry but sticky. It is well to have a clamp for this so as to insure better contact of the patch over the damaged part.

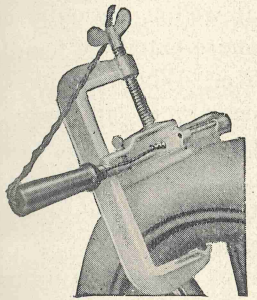


Fig. 124—Electric Tread Vulcanizer.

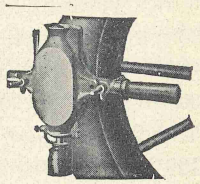


Fig. 125—Steam Vulcanizer.

A number of vulcanizers of the several types mentioned are shown in the accompanying illustrations, the principle being the same in each, the difference in the means by which the heat is furnished and regulated.

For the temporary repair of a blow-out, the most convenient method is to apply the inner tube protector (Fig. 120), to prevent the inner tube being cut by the jagged edges of the casing. A bandage (Fig. 119), may then be laced or securely fastened over the damaged portion of the casing to prevent dirt or pebbles from entering. This is a very satisfactory means for repairing the blow-out sufficiently to reach a repair station.

The damages which extend through the body of the tire tearing the fabric as well as the outer coverings, necessarily require more extensive handling than has been detailed above. When the plies of fabric are broken it is necessary to cut away the successive layers in slightly increasing size over the opening so that when new material is added with sheet rubber between to effect a solid joint, the joints of each layer will overlap.

Attention should be given to the rims as in many instances the hooks of the flanges become jagged or sharp and wear into the fabric near the bead so that a good jar may produce a blow-out. Rust is also a foe to be contended with as it is destructive to the rubber and fabric. For this reason the rims should be kept free of water and moisture and if the rims become rusted they should be cleaned off with emery cloth and given a coat of aluminum paint or shellac. This treatment should be afforded at least once a season as it not only prevents rust but makes removal of the tire easier in case of puncture.

Inner Tubes. The inner tubes should have a life greater than the casing and this is usually the

case if properly cared for. The inner tubes should be protected from light, grease, oils and sharp tools. It is not infrequent that we see inner tubes carelessly folded, thrown in the tool box to bounce and knock around with sharp edged tools and oily waste. Tubes handled in such a manner are hardly fit for use when installed as the oil has attached the fine rubber and the tools have probably produced cuts.

The inner tube should be carried in a special bag or wrapped in soft rubber wrapping, being sprinkled with soap stone or French Chalk. The illustration (Fig. 121) shows the method of folding the tube so as to expel all the air without excessive creasing. After removing the valve stem to allow the escape of air, the tire should be handled as shown in (a), (b) and (c). Compressing the tube as in (c) the stem and cap should be replaced when it may be folded as in (e), (d), (f). The bands used in tying should not be tight and the tube should be refolded at intervals so that the folds may not develop sharp creases which weaken the structure.

It sometimes happens that a small nail punctures the tire and gradually works its way around making punctures at several points by circumferential movement of the casing on the rims. Before inserting a new tube, it is always well to run the hand around the inside of the shoe to make sure that there is no obstruction to cause damage. The use of soapstone or French Chalk is recommended to prevent the generation of heat between the tube and fabric of the casing. Powdered graphite is also efficient as an anti-friction material.

CHAPTER IX.

THE MOTOR: CONSTRUCTION AND CARE.

The electric motor is that part of the electric vehicle which utilizes the electrical energy furnished by the storage battery for the purpose of propelling the vehicle. The energy to the motor is regulated by the controller so that sufficient power may be furnished for operating at any desired speed up to the limit of the apparatus.

The electric motor is no doubt a very familiar and popularly used piece of apparatus, but a brief explanation will probably not be amiss at this point. The quality required in any electric motor is the ability to do a definite amount of work efficiently and immediately when called upon. In general power applications this feature has been characteristic since its introduction, and is the reason for its universal use. This characteristic is very important when applied to the functions of a motor vehicle inasmuch as it makes the operation of the vehicle simple and safe in starting, stopping and traveling. This use of the motor is not new by any means as it dates from the earliest trolley system and has progressed with it over the earth. The motor of the street railway car receives its electrical energy from the distant power house by means of a suspended trolley wire or "third rail," while the electric vehicle motor utilizes that furnished by the storage battery. The energy available from the power house is not limited as far as the needs of a single car are concerned, but, from considerations

of weight and space, it is possible to supply only a limited amount from the storage battery. This restriction means that the manufacturers of these motors must not only furnish a motor capable of turning electrical into mechanical energy, but must provide one which also operates with great efficiency and which will add as little weight as possible

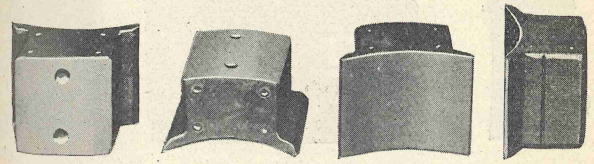


Fig. 126—Field Pole Pieces.

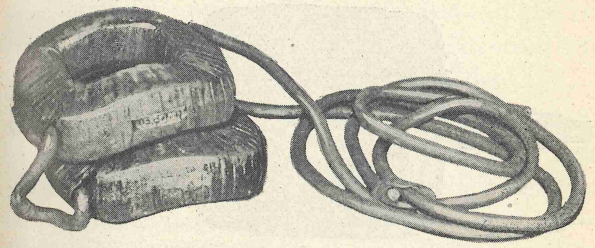


Fig. 127—Field Coils.

to the vehicle. Under ordinary conditions of operation, the power requirements are moderate, but in some instances such as heavy loads, hilly or sandy roads, the use of power many times more than normal is necessitated. The battery is capable of furnishing the energy and the motor must be capable of handling it. This is very severe service, and

it may be interesting as well as instructive to point out at this time that the electric motor is practically the only machine which can be depended upon to

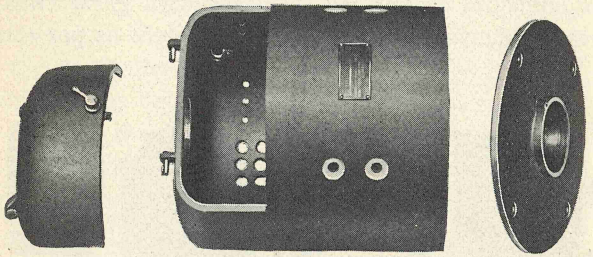


Fig. 128—Motor Frame, Motor Door and End Bearing Plate.

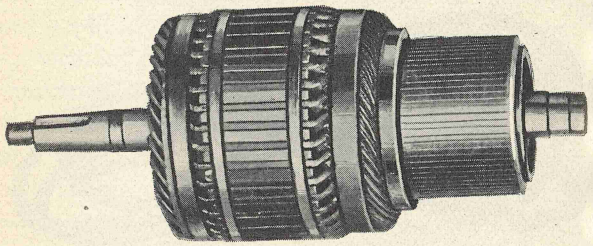


Fig. 129—Armature, Commutator Attached on Right.

withstand such abuse by sustaining such great overloads. The effects will be plainly evident in time, however, and so misuse should be avoided and prevented to the greatest extent. This ability to "deliver the goods," is applicable both figuratively and literally, explaining the claim of reliability and positive operation, under even adverse circumstances,

without making the operating charges prohibitive. The battery must supply the energy and its ability in that direction cannot be questioned when it is known that those of central stations are sometimes called upon to supply the light and power requirements of large cities.

The motor must utilize the current to the best advantage and that this is done must be admitted when the wide application of the electric motor to every art is known. This combination of battery and motor, therefore, offer the most satisfactory and economical method of transportation, limited to safe speeds and moderate but sufficient mileage. The method is most satisfactory because of the very reasons of the electric motor; simplicity, reliability and flexibility; most economical because of the few parts, their smooth running and long life even with hard wear.

In operation, the motor depends upon the phenomena of attraction and repulsion between magnets and wires carrying currents. The magnetism is produced in this case by electromagnets, called Poles (Figs. 126 and 127), constructed of insulated copper wire coiled around cores of laminated iron. The coils and cores are always an even number, and are fastened to the inside of a steel ring known as the frame (Fig. 128). Current supplied by the storage battery to the coils, produces a powerful magnetic effect in the poles and frame; in other words sets up a magnetic field. Rotating between and almost touching the ends of the inward projecting poles, is the Armature (Fig. 129), formed of a mass

of iron laminations over which insulated copper wires are wound. The wires of the armature are coiled in a plane at right angles to the plane of rotation, and their ends are soldered to a sliding contact member, the Commutator, made of copper segments insulated from each other. Current from the storage battery is conducted through the carbon Brushes

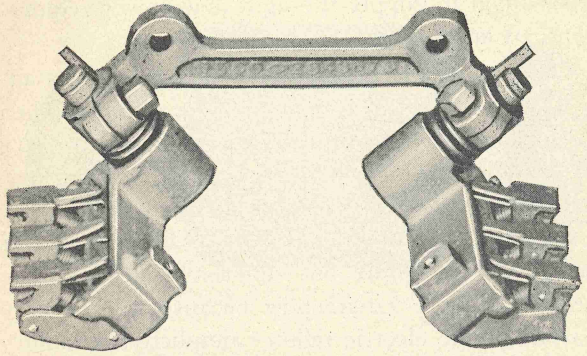


Fig. 130—Brush Yoke Holding Carbon Brushes.

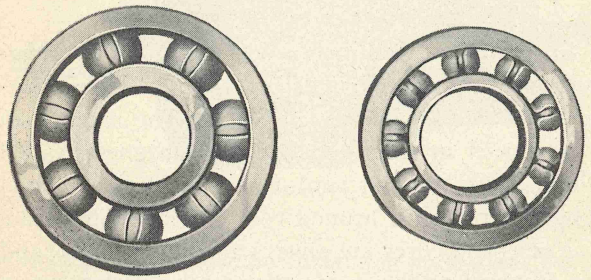


Fig. 131—Ball Bearings for Motor.

(Fig. 130), and commutator to the coils of wire of the armature.

Thus, the current carried in the armature coils, by reacting upon the field, causes the armature to rotate. The Torque, or turning power of the reacting combination, varies with the amount of current in the armature and the strength of the field poles. For electric automobile purposes, the fields are connected in series with the armature, the amount of current in the armature being the same as that in the fields. This combination, known as a Series Motor, is capable of exerting powerful torque in meeting overloads. The amount of current supplied to the armature circuit determines the power developed.

This means that as the controller handle is moved into the positions signifying increased power that more current is being allowed to pass from the battery to the motor, which in turn can exert a greater turning effort. This torque delivered at the shaft of the motor to the chains or gearing, turns the wheels, thus propelling the vehicle. The power may be absorbed in two ways, by propulsion under more difficult conditions, or by increasing the speed with the same conditions. Should the car be running along a smooth, level road and the current to the motor be increased, then the effect will be to produce greater speed. On the other hand, if a grade or hill be encountered, then the speed will diminish in proportion to the rise in elevation. This is natural as it takes more power to ascend a hill than it does to run along the level. Therefore,

should it be desired not only to climb a hill but to maintain constant speed, it is evident that more power must be used, or, coming back to the motor, that more current must be furnished to it in order to accomplish the desired results. The example of the car climbing the hill is probably one which is most easily understood, but the negotiating of every sandy or muddy road amounts to approximately the same thing. This explains why the routing of a vehicle will have a direct result upon the mileage which may be secured from an electric car on a given charge. In fact, since the motor is responsive to the least whim of the operator, it also uses up the power from the battery in proportion to the length and breadth of his whims, so that a careful and considerate driver may be counted upon to secure a greater mileage with less wear and tear than one who uses up power by unnecessary or sudden stops and starts, driving through bad roads or over hills which may be avoided.

The vehicle is equipped with brakes, which may be either of the expanding or contracting type. Adjustments are always provided, generally by spring links, so that there will be no retarding action except when pressure is exerted on the brake pedals. Care should be exercised in making the adjustment so that the brakes do not drag or bind when running. It is evident that dragging brakes would cause the motor to draw a higher current than ordinarily required, and that the mileage on a charge of the battery would be thus reduced. This is one of the first places to look for trouble. If the current consumption, as indicated on the ammeter, is higher than usual for the same road conditions, then it will pay to look for dragging brakes. Naturally, this difficulty should be obviated by periodic mechanical inspection, but it is mentioned in this connection as it has so important a bearing on the motor performance.

In order to make the motor of light weight, and yet rugged in its ability to withstand heavy demands and shocks, only the best quality of iron and copper, the latter used liberally, may be utilized. Ball bearings are practically standard for reasons of low friction, reduction of bearing dimensions, quiet running and durability. They are packed with light cylinder oil, vaseline, or ball bearing grease, which requires only occasional renewal. The brush holders are conveniently located for inspection. The brushes are of carbon composition of ample capacity to operate without sparking and possess long life.

Care of Motors. As explained in the preceding paragraphs, the principles employed in the design and construction of the motors are such as to require a minimum of adjustment and inspection. The arrangement of the parts has simplicity as a special feature so that, should dismantling or repair be necessary, it may be accomplished with little delay and without disturbance of the supplementary mechanism. Being manufactured in large quantities, the parts are standardized and are interchangeable. This is of importance, for to the individual operator it means that repair parts may be readily secured

and installed, and, to the operator of a fleet of vehicles, it allows practically uninterrupted service with but few extra parts or spare equipments.

Ordinarily, the motor requires no attention for months outside of lubrication and adjusting the brushes to the commutator. Inspection may be made frequently, or at least once a month, as to these conditions.

The commutator should have a highly polished smooth surface of a bluish black color. If the commutator is black or shows signs of roughening, it should be carefully polished with fine sandpaper and the dust removed. The commutator bars are insulated from each other by sheet mica, which should not extend up to the commutator surface or it will interfere with the contact of the brushes. If the mica is not undercut, however, then a thin scraper or thin hacksaw blade may be used to remove the material to a depth not exceeding 3/64". Small parts must be carefully removed from the edges of the bars.

Emery Paper Must Not Be Used on the Commutator.

The brushes should be faced to make good contact with the commutator, and move freely in the brush holders so as to allow for any inequalities in the commutator surface and have sufficient pressure on the latter. The shunts or pigtails from the brushes to the holders should be properly attached on each end. The brush holders should be securely fastened into position on the frame and spaced correctly so that there will be the correct number of

commutator segments between the brushes. There are always an even number of brushes and brush holders and, for simplicity, the tendency is to use only two brush sets. There are a great many motors, however, which are supplied with four sets of brushes.

The armature should not only rotate freely in its bearings but should run with the air gap uniform between it and each pole face. Probably the majority of bearings are lubricated with vaseline or light grease, but there are some motors which are designed to use oil. Instructions with the vehicle show the treatment in such a case. To clean a bearing thoroughly, it should be washed well with gasoline, and any foreign material of hard or gritty nature removed. Lubrication is not so much a matter of soaking the machinery in oil or grease, as it is of supplying moderate amounts at regular intervals. In the modern ball bearing motor, six months is probably frequent enough to meet the usual requirements.

Cleanliness is also quite a feature in motor operation and, while the frame and covers are fitted closely so as to prevent even water from entering, yet, the motor being suspended below the vehicle, it is only natural that a certain amount of dirt should find its way into its windings. In the yearly overhauling, therefore, it should be removed. Dry compressed air of about 25 lb. per square inch pressure is admirable for blowing all dirt from the field and armature windings. If air pressure is not avail-

able, then a hand bellows may be used with good effect.

After the windings have been cleaned, they should be inspected for broken leads and defective or chafed insulation which might permit open or short circuits. The field poles should be securely locked to the frame and the field coils rigidly fastened thereto. The above instructions cover the simple items of care and upkeep required under all ordinary circumstances in the yearly overhauling. Monthly, it will usually be found sufficient to inspect the brush holders and contact with the commutator, and every six months to add lubricant. Like all pieces of machinery, a motor is sometimes subject to defects or faults. The most serious of these may be located as follows:

Should the motor fail to rotate when the controller is thrown into a running position, it is evidence of an open circuit or broken connection. If this is in the motor, inspection should be made to see that the brushes move freely in the holder and that no foreign material, such as paper, has found its way between the brushes and the commutator surface. An open circuit in the windings or a break in the connecting leads due to vibration or damage, is also possible and may be readily located and repaired by a competent electrician.

If there is smoke with a disagreeable pungent odor, it is indicative of burning insulation, caused by a short circuit. This will usually be shown by the motor drawing a heavy current. In such a case it is best to discontinue the operation of the vehicle

until an experienced electrician has made an examination of the motor.

These faults given above are possible and do happen, so they are given here, but are found very seldom in the large number of vehicles operating daily in the hands of unskilled attendants.

CHAPTER X.

THE CONTROLLER: CONSTRUCTION AND CARE.

The function of the controller is to regulate the speed and direction of motion of the vehicle. This is accomplished by altering the amount and direction of current supplied to the motor. The current is increased by decreasing the resistance in series with the armature, and by passing successively through several arrangements of field strength. Modern controllers are designed to operate with continuous torque, throughout their range. This means that while changing fom one speed to another the pulling power of the motor is not interrupted, thus avoiding a jerk with each increase of speed and burning of the controller contacts from breaking the current at each step. Reversing the current is accomplished by reversing the relative position (polarity) of the connecting leads from the battery.

The control may be either manual or actuated by a foot pedal according to the requirements of the manufacturer. Usually the controller is located under the seat in a suitable compartment at the driver's left (Fig. 132), in a front hood, or under the car floor. In the latter instance, the control is combined with a wheel steering head and is manipulated by the left hand (Fig. 133), so that the right may be used for the more strenuous duty of steering. A form of control which has been recently introduced is known as the remote control type of controller. In this a small handle or dial regulates, according

to its position, the motion of a number of plunger electro-magnets, which in turn open and close the connections between the battery, resistance and motor. The advantage claimed is ease and simplicity of operation.

Each type and style of control has its advocates and all are safe, positive in action and reliable. The differences are dictated by the requirements of loca-

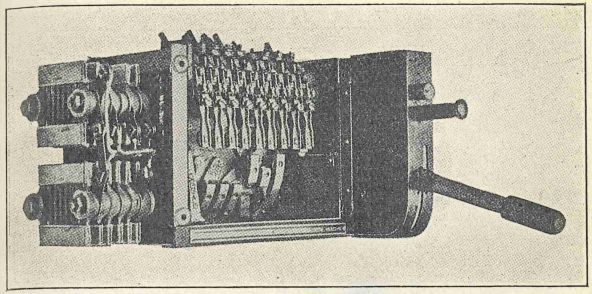


Fig. 132—Drum Controller, Showing Resistance Attached at Left.

tion and the range of speed to be regulated. The prime consideration in each controller is for the utmost simplicity, both in construction and operation. Great study and much experiment has been expended toward that end, having efficiency of operation and positive action clearly in mind.

Structurally, the simple drum controller (Fig. 133), consists of a cylinder, or section of one, rotated by a handle. The drum is provided with copper segments upon its surface, upon which rest copper contact fingers under slight pressure. To the fingers are attached the leads from the battery, motor and

resistance. The segments on the drum connect the fingers electrically in a similar manner to the closing of a switch. When the controller handle is in the "neutral" position no contact is made by the segments and the fingers so that no current flows from one lead to another. This is the normal position of the controller for current "off" and should always be left so when the operator brings the car

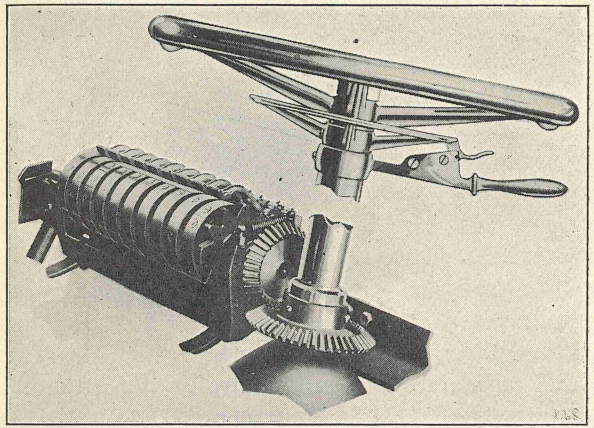


Fig. 133—Controller Under Floor of Car.

to a standstill and leaves it. A number of designs of this type of controller are arranged so that when the handle is brought into this position and is to be left there for a time an auxiliary handle or safety switch may be released, discontinuing any connections between the battery and controller, so that an accidental movement of the controller handle may

not start the vehicle and cause damage. As the drum is rotated the segments are brought under the fingers making a combination of connections between the battery, resistance, and motor field and armature terminals.

The first position is one designed to give low speed and high starting torque so that the vehicle

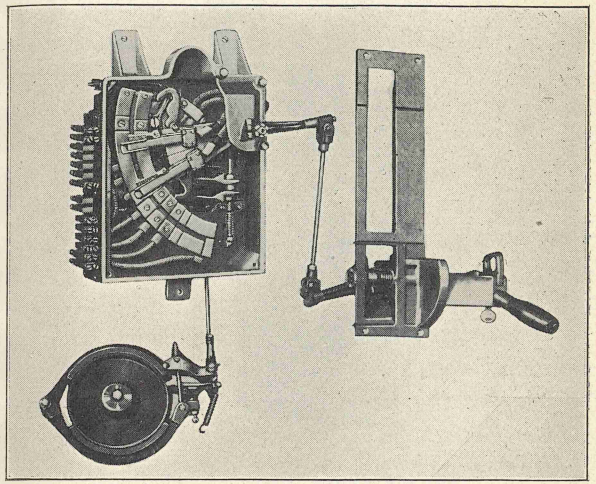


Fig. 134—Controller with Motor Brake.

may be started from rest easily, without jerk, but surely and positively under any condition. Providing that the motor be powerful enough and there be sufficient capacity in the battery, the car will start under practically all conditions. The limiting conditions, however, are when the wheels are either firmly secured in deep mud or sand, etc., or cannot make use of the tractive effort because of their ex-

cessive slipping, as on a sleety pavement. In order to exert the maximum torque, the fields of the motor are arranged in series with each other and with the armature. The motor is then known as a series motor and is capable of exerting a very powerful turning effort. In order to limit the current sup-

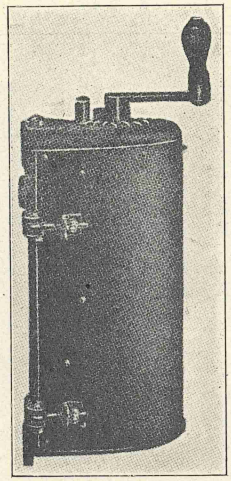


Fig. 135—Heavy Duty Controller.

plied to the motor so that the starting will not be too violent, a resistance is inserted in series with the motor allowing only a smooth slow start.

When the vehicle has once been put in motion, acceleration may be increased more rapidly. It is accomplished through the successive steps of the controller. The second step or point of the controller maintains the same connections as before,

with the exception that the resistance in series with the motor is decreased, and in the third step the resistance is omitted. To further increase the speed, the fields are arranged in parallel with a little resistance placed in series with the armature. The next speed omits the resistance of the preceding. Further increased speed may be gained by further weakening of the field.

It is obvious that, as the speed is increased, more power is used, and that, as the voltage of the battery is practically constant, the current must increase, and, at high speed and in climbing severe hills, it follows that high current will be used. The amount available depends upon the battery capacity. If the battery has a capacity of 150 ampere hours and a current of 100 amperes be drawn continuously, then the vehicle could be operated for approximately one and one-half hours, while if the operation demanded but 20 amperes approximately seven and one-half hours of steady running might be obtained. The greater the current the greater will be the heating of the motor, controller, resistance, etc., and, while each of these is designed to operate under adverse circumstances, they should not be abused where it can be avoided as explained below.

In the explanation just given it was assumed that the cells were connected in series during the speed changes. While this is the case in a number of makes of commercial vehicles, it is not universal, as a parallel arrangement is used with several types of passenger car. The motor combinations remain

relatively the same. The method usually employed in paralleling the battery is to divide the battery in half, thus starting with resistance and half the total battery voltage available. The second and third speeds reduce the resistance in the armature circuit, while the fourth speed operates with all the cells in series with resistance. Thus by combining increasing voltage from the battery, decreased external resistance and weakened motor field, a considerable number of steps of speed increase may be efficiently secured. Up to the present time a range of five or six speed steps has been considered sufficient for smooth acceleration, but some manufacturers are now furnishing controllers having as many as ten steps, augmented by a planetary gear shift for slow running in traffic, or more efficient hill climbing.

A form of controller which is flat and has but two contact making segments, is shown in Fig. 134. The leads are brought to the segments of the stationary sector and those from the battery to the movable contact piece. The advantage claimed for this type of controller is the small number of movable parts and the large contact surfaces.

In the operation of trucks of high capacity it is necessary to have a controller which will handle considerable current without overheating and with small wear of parts so that operation may not be interrupted by the frequent need of renewal. Fig. 135 shows a type of controller similar to that made use of in railway practice where severe service is also met. This controller is of the drum type and provided with insulation and auxiliary features

which prevent sticking or burning of the contact making members.

A controller which has been introduced into electric automobile service recently is known as the "electro-magnetic type." The principle involved consists in making and breaking the contacts of the controller by means of a secondary electrical circuit. The operator of the car, by means of a small dial or lever placed in a comfortable position, regulates the current in this secondary circuit. The primay circuit is that passing through the motor, battery and controller. A number of plunger electromagnets operated by the small current in the secondary circuit are opened and closed according to the position of the dial. The arrangement effected by the opened and closed position of these magnets determines the direction and magnitude of the current in the motor circuit in a similar manner to that negotiated by the segments and fingers of the drum controller. By means of this dial, therefore, all the speed combinations required may be effected, and the advocates of this type claim simplicity of operation and flexibility as its features inasmuch as the dial is very easily moved and the magnets or controller proper may be located in any suitable part of the vehicle. The essential difference distinguishing this controller from those heretofore mentioned is that it is electrically and not mechanically operated. A handle or lever does not operate it positively so that its location does not depend upon any arrangement of links, gears or chains.

Figure 136 shows a developed diagram of connec-

tions effected by the controller in the successive positions or speed points. These points are accomplished by the attaching of a star-wheel to the axis of the control drum which registers with a pawl

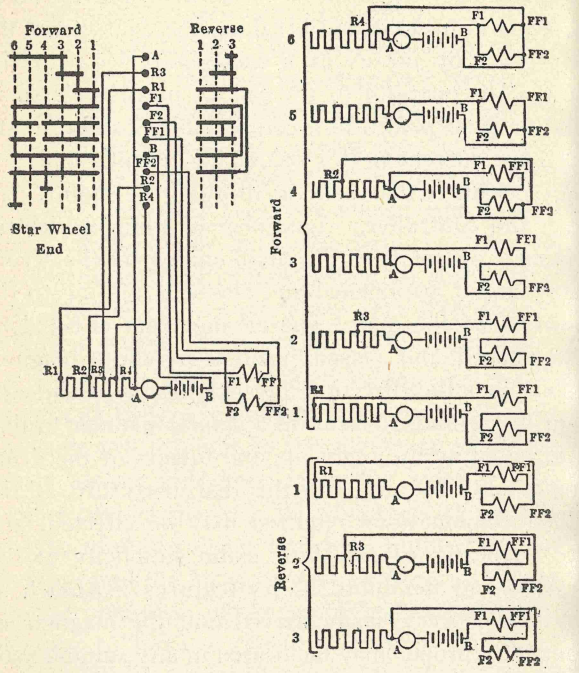


Fig. 136—Development of Connections of Continuous Torque Controller.

having a roller end. Thus, as the drum is rotated, the spring of the pawl forces the end of the latter to roll into the slots of the star-wheel with a sudden movement which can readily be felt by the hand of

the operator and usually distinguished by a clicking sound. In this manner, as the controller is passed from speed to speed, the steps or notches are separate and distinct.

When an auxiliary or safety switch is combined with the controller, it is designed to be placed in the "off" position when the vehicle is brought to rest, and allowed to stand unattended. By this means accidental throwing of the controller into a running position is avoided and when combined with a Yale lock, prevents unauthorized use of the vehicle. In some instances three-point switches are provided, one position for "running," the second for "off" and the other for charging. Practically every make of car has distinctive features in connection with its control and safety devices, but the principles are identical in each case. The differences are in the details designed toward simplicity in the operation of the particular vehicle in question.

In some control methods, the designers have seen fit to utilize the impetus for retarding the motion of the car by adding a notch to the controller which short circuits the armature through resistance, the motor fields being excited from the battery. The motor is then acting as a generator, absorbing the energy of the moving vehicle transmitted through the gears to the motor shaft for the generation of electricity. This action gradually retards the motion and is, therefore, known as an "Electric Brake." When a controller of the side lever type (Fig. 134) is thus equipped, the handle of the controller is pressed forward for the forward speeds, and back

past the neutral or "off" position for electric braking. Pressing the handle further back beyond the electric brake notch, usually tightens a small band brake operating upon a pulley on an extension of the motor shaft. This method of braking is very powerful and is convenient for those who find the operation of brake pedals difficult.

The remarks in the preceding paragraphs on the subject of controllers have been confined to the control of single motor drives. The same principles are applied, however, to the operation of two or four motor equipments, with slight changes in the wiring.

Owing to the simplicity and the ease with which variations of speed and manœuvering may be accomplished, the electric drive has reached high favor in a great number of heavy duty vehicle applications. Among these may be mentioned tractors for heavy materials such as lumber, coal, machinery, building materials, etc., as well as coaches and omnibuses.

Care. The arcing at the points of a knife switch when slowly opened is no doubt familiar to most readers, and the appearance of the scarred metal is evidence that the switch was carelessly opened. This action takes place to a certain extent in the controller if the drum is held between the notches. The fingers are held onto the segments of the drum by a moderate pressure and are faced to make good contact. Should the contact be poor, however, touching at only a few points, or the finger slowly drawn from the segment, then there will be an arc

between them causing a blistered surface. This can easily be avoided by having the contact surfaces well faced with proper pressure and the spring of the pawl tightened sufficiently to cause the drum to stop exactly in the notch. When working on the controller it is well to disconnect the battery leads so as to avoid burns or short circuits.

Lubrication should be frequent, regular and moderate. About once a week when in daily service, inspection should be made and the fingers adjusted to an even, moderate tension. They should be run parallel with the drum and faced with sandpaper so as to make good contact. Badly burned fingers should be replaced and fitted into position. The drum segments should be kept bright and clean and lubricated by being wiped with a linen rag and a small amount of vaseline. If they are blistered or pitted, they should be smoothed down with sandpaper. When it is necessary to face fingers to the drum, the sandpapering should be done upon the fingers rather than the drum segments as the latter are not as easily replaced as the fingers.

CHAPTER XI.

THE CHASSIS: ITS COMPONENTS: THEIR UPKEEP.

There are two broad divisions in the field of electric cars, commonly designated as passenger and commercial vehicles. The former include the small runabouts, coupes or limousines, while the latter are commonly called trucks. In this latter classification should also be found the industrial vehicles electrically propelled, such as baggage and dock trucks as well as storage battery cranes and locomotives. To develop detailed descriptions of the many forms in which these vehicles may be found is neither practicable in a volume of this character, nor is it necessary, as the principles are identical in all storage battery vehicles, and, when once understood, the differences in design may be readily grasped.

The construction of bodies has received skilful and exact treatment for many years. Coach-building is not a new industry by any means and the advent of the automobile has simply opened a broader field of endeavor to the artisans of that trade. True, the shapes and materials used have changed somwhat, but in the pleasure car, the requirements of comfort and protection from wind or weather are identical The lines of the body are shaped so as to be pleasing to the eye and oppose the least resistance to the wind. The necessity for strength and light weight have brought about the use of aluminum for panels, mouldings and seams, displacing wood to a great extent.

The utmost simplicity and economy may be observed in the design of bodies intended for salesmen's, inspectors', or other business runabouts, while on the other hand the identical chassis may be surmounted with an enclosed type of body, which, in lavish furnishing and refinements for luxurious comfort, might excel the splendor of royal equipages. The features of strength, simplicity and economy of operation, however, are as well developed in the most commonplace looking carrier of merchandise, as in the most exquisitely furnished brougham. The trimmings and fittings are matters of taste and choice, dictated by the requirements of the owner.

With the introduction of the motor vehicle into the transportation departments of the various industries, new requirements were placed upon the design of the chassis and bodies used. These were the result of carrying heavier loads and moving at higher speeds than were possible with the horse drawn vehicles. As one of the economies of the motor vehicle consists in moving its loads at these greater speeds, innovations were made in providing many varieties of special bodies, combining strength, light weight and quick loading and unloading facilities. Bodies of such construction are characteristic of motor vehicles in general and no doubt familiar to all.

In electric vehicle practice the word chassis is used to designate the parts of the car other than the battery and body. These parts consist of the wheels, frame and supporting springs as well as

the controller, motor, gearing and steering apparatus. The motor and controller are pieces of electrical apparatus and are treated separately in Chapters IX. and X.

Frame. The body with its load is supported upon a strong, but somewhat flexible, structure known as the Frame (Fig. 137), which in turn rests on springs attached to the front and rear axles. By this arrangement, as much of the weight of the vehicle as possible is carried on the springs, cushioning the shocks and reducing the vibration.

The frame is composed of two side members and several cross members, so that with proper riveting

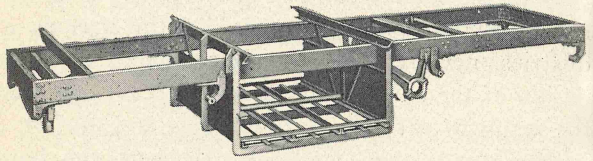


Fig. 137—Frame with Underslung Battery Cradle.

the parts may be combined into a unit of sufficient strength to carry the load and maintain the proper relation between the sections of the driving gear under the road shocks or the distorting effects of the inequalities of the road surface. Bracing straps, gusset plates and kindred means of reinforcement are used to effect the desired result. Pressed steel forms are usually made use of for the purpose as they combine the requisite strength with light weight. The frame shapes differ widely, depending upon the size and service requirements of the vehicle. Very often the front ends are cambered to permit turning in a smaller radius. The outsiders and spring stubs are forged steel and are riveted to the ends of the side members.

In pleasure vehicle construction the frame is frequently raised at a point in front of the rear axle to permit the running board and floor of the car to rest lower than if the entire frame were on one level. It is necessary for the rear part of the frame to be high enough to provide sufficient clearance between the cross members and the rear axle housing.

The storage battery assembled in several trays may either be underslung from the frame in a cradle or carried on cross members. While there is no rule or standard practice in this regard, it will usually be found that, with commercial vehicles, the battery is underslung, and that in pleasure car design the number of trays are divided and supported slightly below the frame level under hoods at the front and rear. Electric vehicles may be readily recognized at a distance by these characteristic features of arrangement.

Springs. In order that the shocks and jars incidental to travel over roads not absolutely smooth may be absorbed and not transmitted to machinery and passengers, considerable attention has been given to the construction of springs. Special formulae have been developed for treating the steels used, and extreme care is exercised in the fabrication of

the leaves so that the built leaf spring will be able to absorb the shocks and vibration, and, at the same time, carry a considerable weight without sustaining permanent deflection or breakage. The length and form of spring used, such as elliptic, semi-elliptic, three-quarter elliptic, helical or platform, or combinations of these, depend upon the weight, speed and class of service in which the vehicle is to be used as well as upon the individual choice of the designer.

The springs rest upon specially formed seats forged from the axle proper or welded to it. These seats are curved so as to conform to the curvature of the spring and are drilled so that two "U" shaped rods of steel, known as clips, may be brought over the plate resting on the upper spring leaf, through the holes of the seat, and secured by nuts and lock nuts. The ends of the springs are connected by bolts and bushings. As there is great opportunity for wear at these points, grease or oil cups are usually furnished for lubricating these bearing surfaces.

Axles. Axles are very important parts of a motor car chassis because, upon their freedom from failure, depends the safety of the passengers. To fulfill this requirement, as well as to support the load properly, they must be strong.

Front axles not only support their share of the load, but are first to receive the shocks and jars due to holes and ruts in the road. Strength is required to meet these demands, and then comes the consideration of utilizing the least weight of material sufficient to provide that support. Steels of special composition, properly forged and heat treated, have been developed in order to combine the necessary strength with light weight. Front axles of I-beam section are probably most extensively used, although tubular shapes have been popular on the lighter types of electrics.

Reference to Fig. 138 will clearly indicate the assembly of the axle ends by means of which the steering mechanism is combined with the load sup-

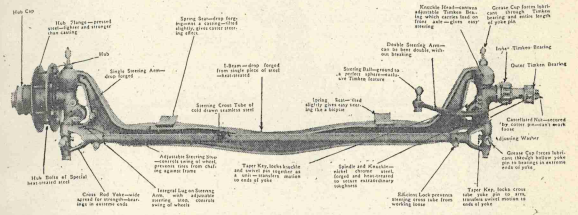


Fig. 138—Front Axle Construction.

porting members. The ends of the axle are yoked so that a knuckle with spindle for the wheel and steering arm may each be mounted in anti-friction bearings, thus permitting both free rolling of the wheels and steering with a powerful leverage. The projecting arms of the knuckles at each end of the axle are connected by a "cross rod" or "tie bar" so that the movement of both wheels in steering will be identical. The motion imparted by the steering gear is transmitted to the tie bar by a rod known as a "drag link." The connection between the drag link and steering arm is either a ball and socket

joint, enclosed in a grease boot, or a yoke and pin arrangement provided with bearings.

It will be noted that all bearing joints, susceptible either to radial load or end thrust, are provided with anti-friction bearings so that wear and resistance to motion may be reduced to a negligible quantity.

The seats upon which the springs rest, and to which they are secured by the clips, may either be

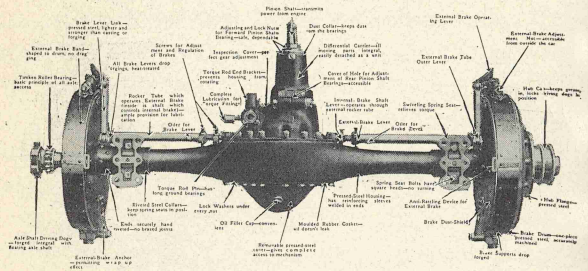


Fig. 139—Rear Axle Construction.

integral with the axle or forged separately and fastened rigidly to it. The upper spring seat surface is curved so as to give greater bearing surface for the spring, and, in some cases, tilted slightly to obtain a caster steering effect.

Rear axles may be divided into two classes, according to the service in which they are used; pleasure or commercial. Front axles are practically the same for both classes of service, the proportions being more generous, of course, when used upon trucks. Vehicles of light weight may use the

construction developed for the pleasure car chassis, but those designed for heavy duty must necessarily be provided with rear axle equipment capable of transmitting power efficiently under the stresses of heavy load and poor road conditions. The live axle is charactertistic of the light car, while the

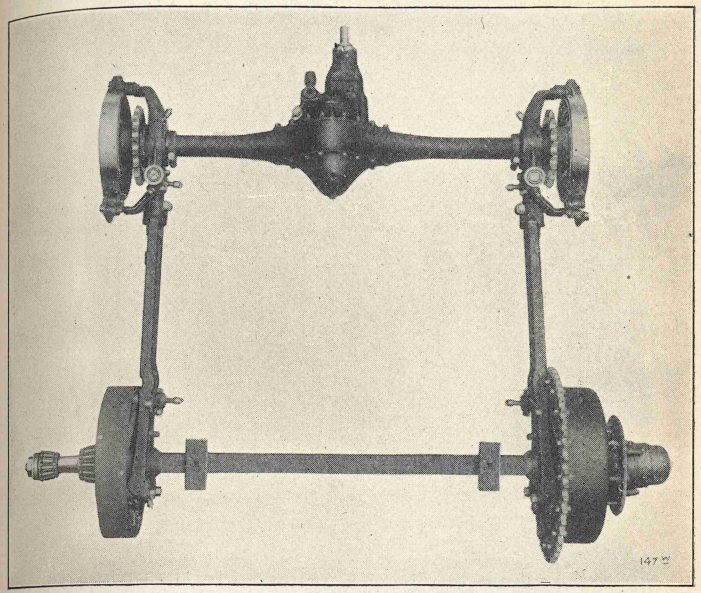


Fig. 140—Dead Axle and Countershaft Assembly.

dead axle with countershaft and side chain drive is, with few exceptions, used on the majority of commercial vehicle applications. The live axle (Fig. 139) not only supports the load, but transmits the power from the motor, dividing it through the differential gear to the wheels. When the load is

carried by the housing and the enclosed shafts transmit the power to the wheels, then the term "full-floating" is applied to the axle because the shafts are said to float within the housing. Semi- or three-quarter floating refers to axles in which the carrying and torque functions are combined in approximately the amount indicated in the term.

The dead axle (Fig. 140) is the familiar form which is used to support the load alone, the driving being done by chain gearing from the countershaft to the rear wheels.

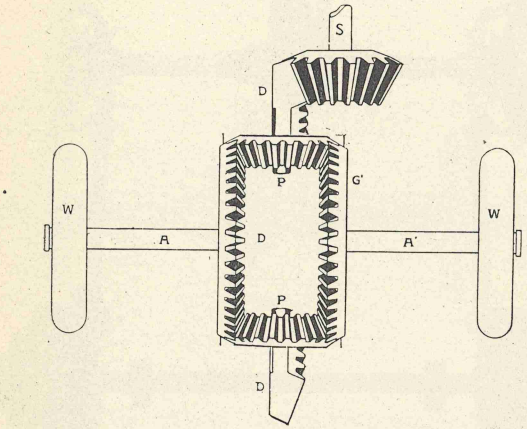


Fig. 141—Diagram of Differential Gearing.

Differential Gear. In order that the power from the motor may be applied equally to both driving wheels and yet permit them to revolve at different speeds, as when turning a curve, the differential gear is employed. It is necessary with either live or dead axle construction. With live

axles it is contained in the housing but with dead axle construction it is incorporated in the countershaft assembly. To reduce wear and make for efficient running the differential casing is made oil tight so that light grease or heavy oil may be held, making adjustment seldom required but assuring proper lubrication.

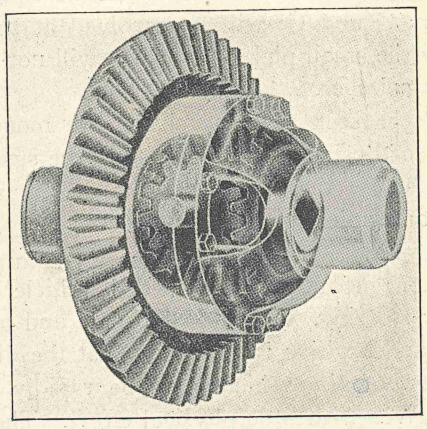


Fig. 142—Phantom View of Differential.

With the aid of Fig. 141, the following explanation may serve to give a clear idea of the operation of the differential, an important but unfamiliar detail of the transmission. In the illustration shown the driven gear D is meshed with a bevel pinion S on the driving shaft, but, of course, the driven gear may be of the spur type operated by silent chain or a gear meshed with a worm shaft. The four small bevel pinions P are held on spindles in the plane

of the gear D, and their teeth mesh with the bevel gears G and G^1 attached to the axle shaft ends. Thus, when G is stationary, the pinions P will roll over its surface and also upon their own axes, turning G^1. Or, if the resistance to motion of the wheel W is greater than that of W^1, as in turning a corner, then G will turn but at a lesser speed than G^1. When the resistance of both wheels is equal, then the gears G and G^1 will be revolved at the same speed by the small pinions P which will not revolve on their spindles.

It will be seen that the shafts are mounted in bearings of design capable of taking the stresses of radial load or thrust so that the action will be smooth and quiet running.

Steering Gear. One of the most important mechanisms of any self-propelled vehicle is that used for steering. It must be simple and quick to operate and positive in action so that the direction of motion of the vehicle may be rapidly altered by the driver with little physical effort. The steering is effected by means of a series of links which transfer the small movements of the guiding wheel to the steering arms attached to the knuckles upon which the wheels are mounted, as explained above under "Axles."

The steering column is furnished at the lower end with some form of reduction gear when a steering wheel is used, which permits a small rotary movement of the steering wheel to be transformed to a reciprocating movement of the drag link. This gear reduction may be by pinion and spur sector

(Fig. 143), spur gear and rack, or worm and gear. At the present time the pinion and sector type is very widely used on electric commercial vehicles.

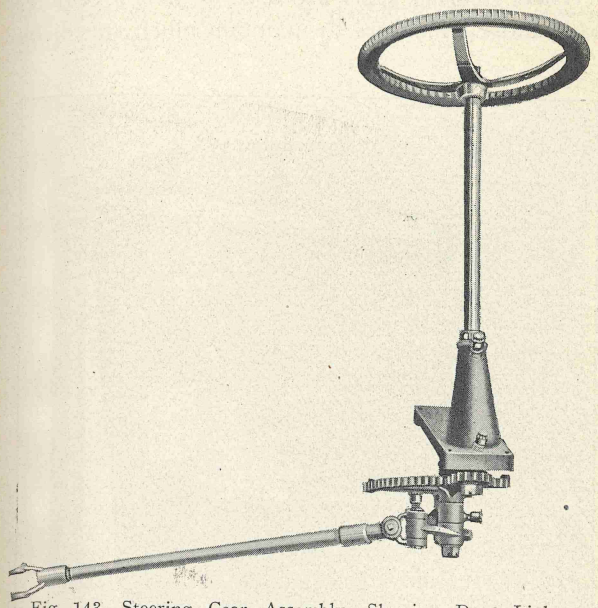


Fig. 143—Steering Gear Assembly, Showing Drag Link.

For light commercial and pleasure vehicles, the horizontal steering lever (Fig. 144) is very extensively used, being practically the standard on account of its big leverage and quick action. The horizontal lever is arranged to swing into a vertical position over the steering column to which it is attached out of the way of the driver when not in use. At the lower end a knuckle with a ball end

rests in the socket of the drag link. These connections are usually furnished with ball bearing and spring adjustments so that friction may be reduced and the handle kept free of vibration

Wheel steering gears are used on heavy vehicles, or on those which are to maintain much speed, be-

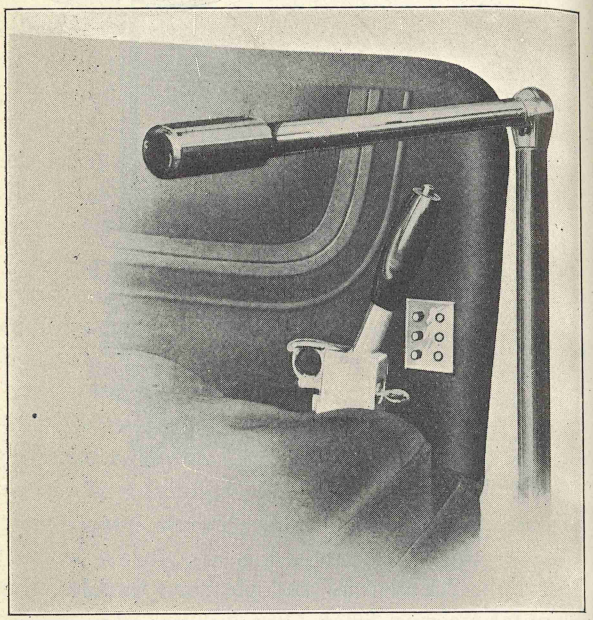


Fig. 144—Lever Steering Arm.

cause they are irreversible; that is, a jar or blow on the road wheels will not alter the direction of motion of the vehicle, as might occur with the steering rod previously described.

On the heavier commercial vehicles the steering wheel is standard and with it is very often combined the lever to the drum of the controller. Fig. 145 shows one method of arranging the controller handle upon the steering column in a manner similar to that employed in gasoline vehicle steering and control.

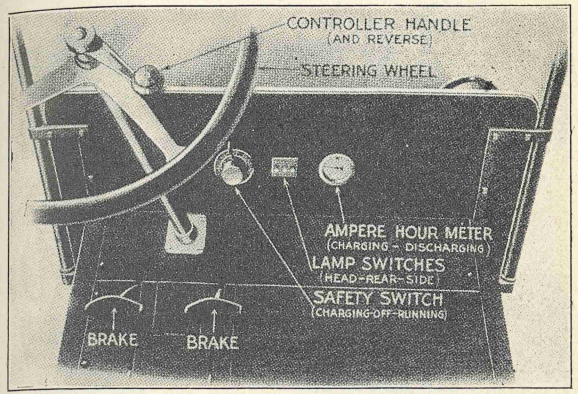


Fig. 145—Steering Wheel, Controller and Dashboard.

Bearings. It has been pointed out in the descriptions in the preceding pages how important a part in the operation of the electric vehicle anti-friction bearings play. In order that the greatest mileage may be secured from the battery capacity available, friction must be reduced to a minimum. Practically every moving part, which is susceptible to wear, is fitted with a type of bearing most suitable to the use. The designs, Fig. 146, show the several types very clearly.

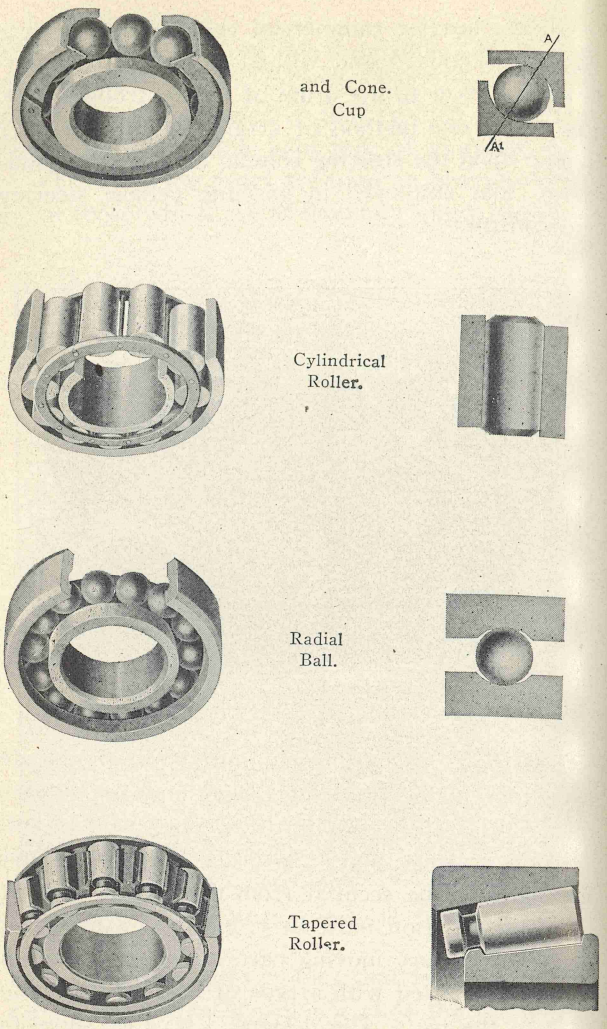


Fig. 146—Types of Anti-Friction Bearings.

It will be found that, under identical conditions in cars of different make, different types of bearings are used. These differences of opinion naturally exist so that several styles of mounting are employed. With very few exceptions, inspection will show the bearing equipment to be of liberal proportions for the loads sustained in order that

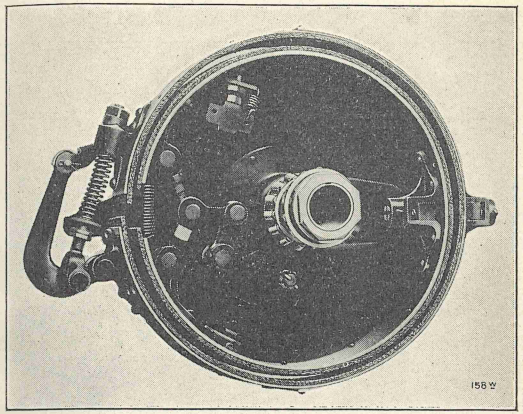


Fig. 147—Brake, Outer Drum Removed.

each running part may have the greatest freedom in motion.

Brakes. One of the most important features of the motor car control is the means used for retardation. If the car refuses to start, it is possible to get out and walk, but it is not pleasant to contemplate a ride down grades with brakes which are of little value. Vehicles of up-to-date construction are in practically all cases furnished with brakes

of ample size to bring the vehicle to stop without jar or suddenness.

The brakes are operated by pressure exerted on the brake pedals situated within easy reach of the driver's feet. The rods from the pedals usually transfer the pedal pressure to equalizing bars suspended from the frame so that the pressure will be equal upon both brake drums of the rear wheels or

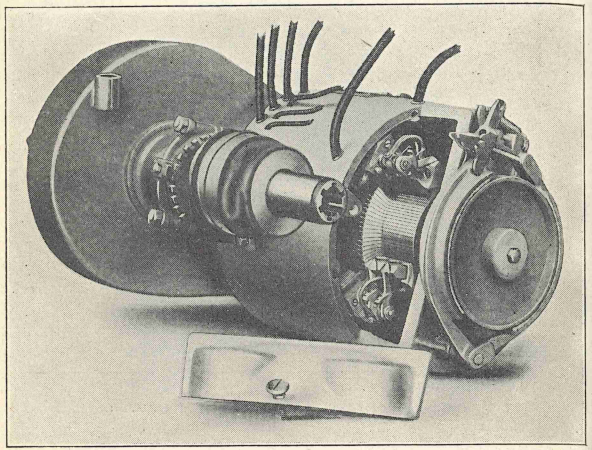


Fig. 148—Band Brake on Motor Shaft.

countershaft. Brake drums are placed in many cases on the countershaft for emergency brake use, and on the rear wheels for general service braking. Frequently hand levers with ratchet locks are used for emergency brake control instead of a foot pedal.

Most generally the construction of the brakes is of the type shown in Fig. 147. The two semi-circular shoes are pivoted at one end and held at the other by a cam or toggle linkage. The force exerted on the brake levers causes these links to expand the shoes against the surface of the drum, retaring the motion of the vehicle evenly and gradually. When the shoes operate on the inner surface of the drum they are called "internal expanding," and when the pressure is exerted on the outer drum surface, the term "external expanding" is used. A band brake is shown in Fig. 148, contracting on a pulley keyed to an extension of the motor shaft.

In this particular design, the friction brake is operated in conjunction with an electric brake. The electric brake is secured by short circuiting the motor armature through resistance, energizing the fields from the battery. The connections for accomplishing this are made when the controller handle at the left of the driver is brought back slightly beyond "off" position. Under these conditions the motor acts as a dynamo, using the momentum of the car to generate electricity. The greater the speed, the greater will be the braking action automatically. As the controller handle is brought back still further, pressure is applied to the band brake on the motor pulley exerting a very powerful retarding force. This combination is very powerful and quick acting because of the big leverage obtained through the reduction gearing. Some manufacturers of pleasure vehicles consider it very valuable in rendering braking and stopping physically easy and reliable for drivers of the gentler sex.

The brake shoes are faced with friction material such as the heat resisting substances composed of asbestos interwoven with copper gauze. These facings gradually wear down and must be renewed; how often renewal is necessary depends upon the amount of use to which the brakes are subjected.

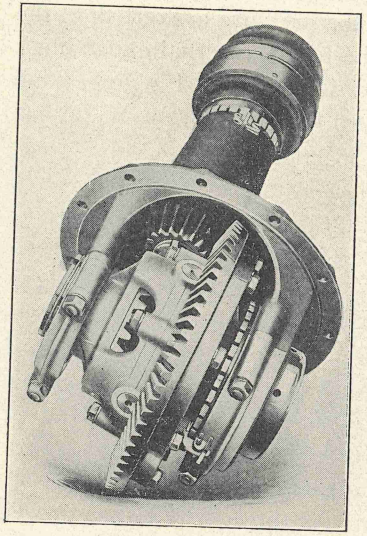


Fig. 149—Bevel Gear Drive.

Transmission. Experience has shown that electric motors of comparatively high speed, having ranges of from 900 to 1,600 revolutions per minute, are satisfactory for vehicle use. As the driving wheels travel at speeds considerably less that these, however, it is necessary to interpose some means

of reduction gearing between the motor and the wheel. There are many methods of accomplishing this result such as by sprockets and chains, shaft and bevel gear, or worm and gear. Each of these means is both efficient and enduring, and represents the study and experiments of the most skillful designers, supplemented by many years of experience from the many vehicles in constant service.

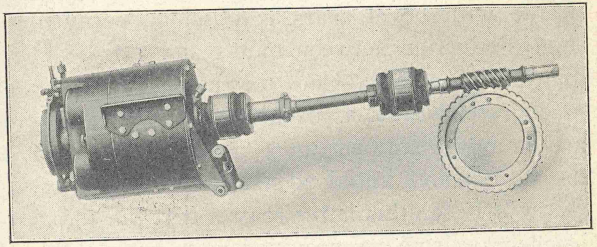


Fig. 150—Worm and Gear Drive.

Probably the greatest number of electric cars at the present time are equipped with a double reduction transmission. The first reduction is in many cases a silent chain gearing, enclosed in an oil tight case, so that the adjustments may be undisturbed by entrance of grit or rust. The larger sprocket of this reduction is connected through a differential gear on the countershaft to the rear wheels by roller chain drive, or by means of shaft with universal joints to a differential gear in the rear axle construction. In commercial vehicles the final drive from countershaft by side chains is most common, while the shaft drive is much favored for pleas-

ure vehicles because of its neat, noiseless and efficient character.

Shaft drives are used either with bevel gear, Fig. 149, or worm drive to the rear axle. The worm and gear reduction is the most recent of refinements in electric vehicle design. The illustrations, Fig. 150, show the features very clearly. The advantages claimed for the worm drive are that a greater ratio of speed reduction than practicable with bevel gears is possible, permitting a single reduction between motor and rear axle, and that instead of a tendency to wear out of alignment in course of time, as occurs with bevel gears, use makes the adjustment more perfect, providing that the design and initial adjustments have been correct. It is for this latter reason that the shafts for bevel gear drive are provided with means for making the necessary changes in adjustment, while the worm and gear mounting is enclosed so that changes cannot be made from without.

The ends of the shaft connecting the motor and rear axle constructions do not remain the same horizontal plane as the spring action raises and lowers the motor end of the shaft, under the infiuence of uneven road surface. In order to transmit the power to the rear axle efficiently, therefore, the shaft must possess flexibility to compensate for the changes of alignment throughout the range of spring action. This flexibility is secured by the use of universal joints of neat design, as shown in Fig. 151.

A unique form of drive is shown in Fig. 153, in

which the motor drives through an enclosed silent chain and floating shaft, with two universal joints, to a "herring-bone" gear connecting with the differential gear in the rear axle housing. The rear axle construction is arranged so that the axle shafts

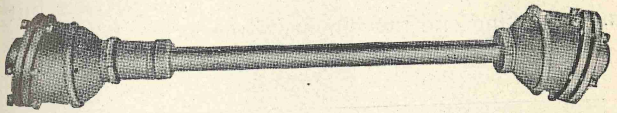


Fig. 151—Universal Joints with Slip.

carry no load and the differential is relieved of end thrust. The outer ends of the axle shafts are furnished with clutches, engaging with the wheel hub. This type of axle is known as "full floating" be-

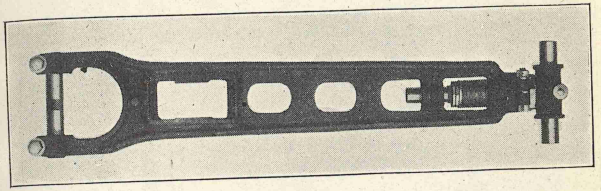


Fig. 152—Radius Rod.

cause the load is carried by the housing and the axle shafts may be drawn out from the hubs without disturbing the rest of the assembly.

In order to preserve the proper distance between the sprockets of the chain gearing, adjustable spacing members are employed, called "radius rods" (Fig. 152). These maintain the chain in proper tension and secure the countershaft into a unit with the rear assembly. They are also used when shaft

drive is employed to keep the rear axle in proper relation with the frame. In some designs the driving shaft is held in a tubular member, generally attached to the frame so that it serves as a radius rod, permitting the axle to move up and down, due to the influence of inequalities of road surface but not allowing end movement of the axle. When the

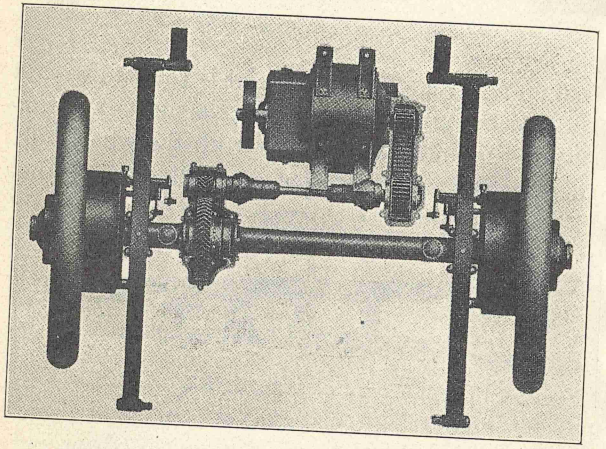


Fig. 153—Shaft Drive with "Herring-Bone" Gear.

torsional, or turning strains to which the axle housing is subjected when driving, are taken by a single member, it is known as a "torsion rod" (Fig. 154).

Instead of supporting the motor from the frame, the design of drive shown in Fig. 155 makes use of a motor enclosed in the rear axle housing. The shaft of the motor armature is hollow so that the drive shafts may extend through from the differential sockets into the centre of each hollow rear wheel. The differential is located at one end of the hollow armature shaft. On the wheel end of each shaft a pinion is located which transmits

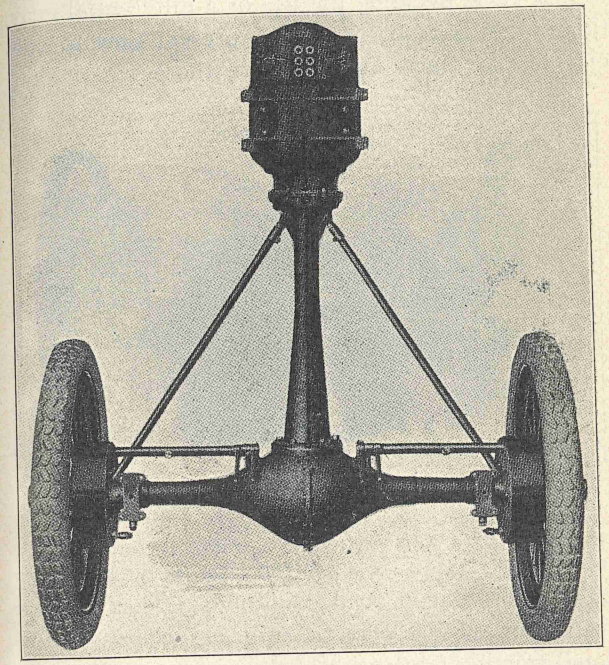


Fig. 154—Shaft Drive, Showing Torsion Rod.

the power to the rim gear on the inside of the wheel through the two idler gears. The fully enclosed construction and simplicity of the parts are claimed by the manufacturers to be important factors in making the drive efficient and durable.

In the descriptions of drive methods typified in the preceding paragraphs, reference has been made only to the use of one-motor equipments. Although the earlier electric vehicles made use of two motors geared to the wheels by single spur gear and concentric rack, avoiding the use of a differential gear, this design is restricted at the present time to special cases. Such instances are those where con-

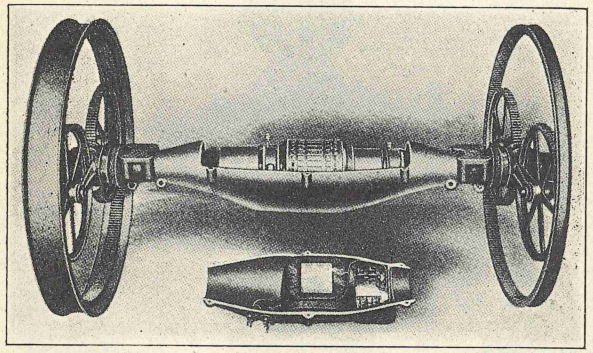


Fig. 155—Motor Within Axle Housing.

siderable traction is required for moving heavy loads over difficult road conditions. Then two or even four motors may be utilized, securing additional traction by the use of the front as well as the rear wheels for driving.

In Fig. 156 is shown a rear axle construction used on a seven-ton, four-motor truck. The axle forgings are made of yoke form in a vertical plane and bored out to receive the trunnions which are part of the motor casing. The motors slip into

these casings and are clamped in position. A pinion on the end of the motor shaft engages with a spur gear meshing with an internal gear bolted to the wheel. This gearing is enclosed by projecting flanges ground to form a grease tight joint. At the front the two casings swivel in the axle and are connected to the steering gear. At the rear they are maintained in fixed relation, holding the wheels permanently parallel and in line with the truck.

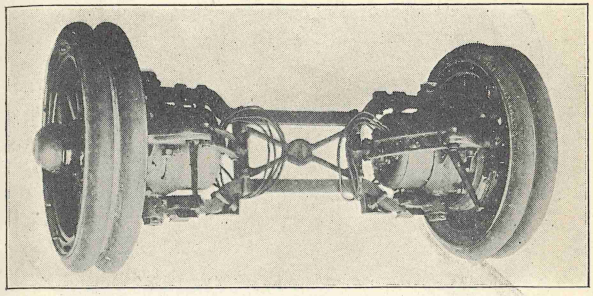


Fig. 156—Rear Axle of Four Motor Drive.

A two-motor drive is shown in Fig. 157. The spur concentric gearing is enclosed in this design also, and the motors are held in position between two steel channels which form the rear axle.

Another type of two or four-wheel drive is accomplished by placing the motors within the metal wheels. As shown in Fig. 158, pinions on each end of the motor shaft engage with the gear racks on the wheel. The motor is set at a slight angle to the plane of the wheel so that the pinions engage with their respective halves of the cog-rack, being

free of the other half. By this couple arrangement a single speed reduction is effected without the use of a countershaft.

Sets of either two or four wheels of this construction may be employed and the steering may be either by the forward wheels or through all four wheels for fine manoeuvring. When the two for-

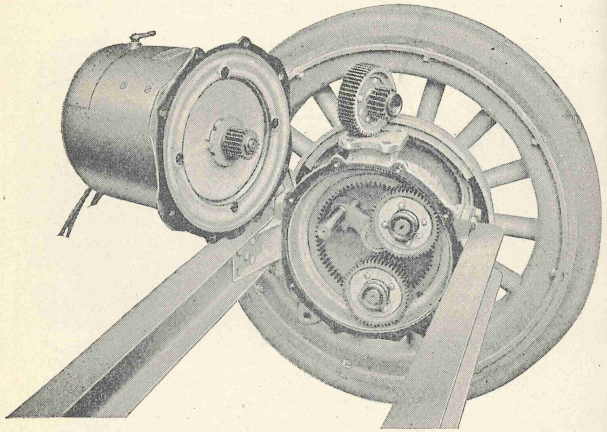


Fig. 157—Detail of Type of Two Motor Drive.

ward wheels are used as the tractors, then the rear or drawn wheels may be large steel tired ones such as ordinarily used on horse-drawn vehicles, thereby avoiding the use of rubber tires. The road conditions, together with the service requirements of load and speed, are the determining factors in the specification of the amount of traction necessary and the efficiency of applying it by means of two or four-wheel drive.

Lighting. The electric lighting of motor vehicles is indeed most popular. For the storage battery propelled car it involves only the wiring of the lighting fixtures to the battery through switches placed within convenient reach of the driver. The lighting circuits are fused so injury from accidental short-circuits may be reduced to minimum. The lamps are made in a great variety of styles and

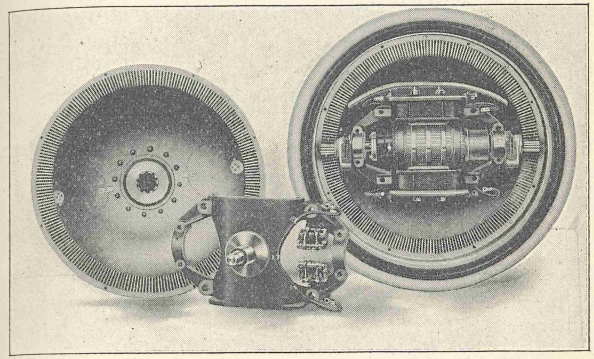


Fig. 158—Motor Contained Within Driving Wheel.

shapes and may be placed in positions most suitable to the owner's requirements. Arrangements are very often made for trouble lamps which may be attached to a receptacle beneath the controller for giving light to inspect damage to tires, loosened nuts or the like.

The meters are, in practically all instances, provided with a lamp of small candle power shaded so as to illuminate the dial without glaring into the eyes of the observer. This light may be lit by

pressure on a button underneath the pad of the carpet. Withdrawing the pressure allows the spring to open the circuit. Hitherto the incandescent bulbs used have been of the carbon filament type, but the remarkable developments in the construction of the tungsten lamp have made its use possible for automobile lighting for voltages such as are found in electric vehicle service. The shapes and sizes are suitably designed for use in the different fixtures.

Recently the bayonet candelabra base lamps have been adopted as standard by the Electric Vehicle Association of America. There are a number of vehicles in use at the present time, however, equipped with candelabra screw base and medium screw base sockets so that lamps may be purchased to fit any of these receptacles. New vehicles will be supplied with the standardized product and it is recommended, where alterations in used cars are made, that they also be equipped with the sockets for the candelabra bayonet base lamps.

Wiring. The energy from the storage battery is conducted to the electric motor through insulated wires. Actually, the wiring is from the battery to the controller and thence to the motor, in order that the speed of the motor may be regulated by simply changing the position of the controller handle. In many makes of vehicles a main switch for opening the circuit is included so that there may be no danger of starting the vehicle unexpectedly or its use by those unauthorized. For the latter purpose, the controllers of pleasure vehicles, which may stand unattended for long periods, are furnished with

Yale locks, so that the handle cannot be moved until the operator has taken the driving position, inserted and turned the key, which then, cannot be moved until the handle is brought back to the "off" position.

The wiring is done in a very careful manner, giving attention to the use of material of sufficient size to obviate any tendency to heat at normal loads or overloads. The insulation must be good so that there may be no leakage to the frame or between wires. The installation of the wiring must be such that it will be secure in position and not liable to mechanical injury, which would impair its elec-

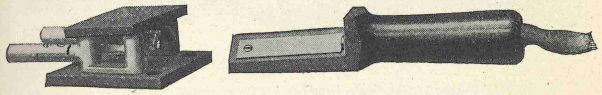


Fig. 159—Charging Plug and Receptacle.

trical efficiency. To preclude any such possibility, the most approved installations are made by enclosing the leads in metal tubing, proof against injury and moisture. Naturally it is important that all connections be firm and tight so that there may be no sparking or arcing. The use of the electric is not prohibited on docks, piers or in buildings because of the small likelihood of its producing combustion.

The above facts in regard to installation are stated not so much to explain the original safe character of the vehicle, as that is well known, as to emphasize that changes in wiring should be

made by competent electricians, so that by no remote possibility can any inflammable material be ignited. Due to improvements and care in this direction, the insurance rate on electric vehicles has decreased and further reductions are being made periodically.

For convenience in making the necessary connections for charging, a charging plug and receptacle is furnished. The receptacle is fastened to the frame of the vehicle and connected to the storage

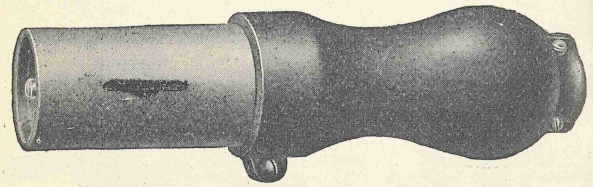


Fig. 160—Standardized Charging Plug.

battery. With the controller in the "off" position and all switches open, the charging plug, wired to the charging board, is inserted in the receptacle, making the proper connections quickly and without danger of heating. The charging plug and receptacle standardized by the Electric Vehicle Association of America is shown in Figs. 160 and 161. The inner ring of the receptacle should be connected to the negative pole of the battery and the outer ring to the positive terminal. Likewise, the negative and positive wires of the charging cable should be connected to the inner rod and outer shell of the plug. By following this method it will be possible

to place a vehicle on charge from any plug without danger of short circuiting or charging the battery in the wrong direction. At the present time there are several styles of plug and receptacle in use, Fig. 159 showing a popular make, but they are more or less defective in strength and there is no uniformity in size or in arrangement of polarity so that interchangeability is not always possible. To obviate this difficulty, the standard adopted as described above has been received very favorably, permitting the car to be run into any charging station for a "Boost."

In addition to the motor used for vehicle propulsion, motors are employed for operating winches, cranes, dumping bodies, pumps and similar devices. These are operated by controllers constructed for the purpose and wired to the battery independently. The same rules of installation apply in these cases as in the regular vehicle wiring.

The wiring of a bell or signal horn is a simple matter, the only precaution necessary being to connect the device across such a number of cells that it will not be damaged by too high a voltage. It is preferable to use a bell connected across the entire series of cells, and as a matter of fact, that is what is done with but few exceptions. The bell is rung either by means of a button in the controller handle or by a floor push, so that in approaching a street intersection or in attempting to pass another vehicle, the signal may be given without perceptible effort on the part of the driver.

MECHANICAL PARTS—THEIR UPKEEP.

It is stated without fear of contradiction that there is no piece of machinery which will perform continuously without care and attention. The electric vehicle is no exception in this respect. However, the number of moving parts is small and they are neither delicate nor complicated. The most important requirement is lubrication. The subject of lubrication is so important to machinery of all kinds that many treatises have been devoted to the exposition of the details of the theory and practice concerned. For the purposes of electric automobile operation, however, no theoretical consideration is necessary, the simple rules, "To err on the side of too much rather than too little," and "Add in small amounts often rather than large amounts seldom," being sufficient for all practical purposes.

Vehicles of both the commercial and pleasure types are provided with means for lubrication depending upon the character of the contact surfaces. Oil cups, grease cups and grease boots may be mentioned among these. Wheel bearings are packed with grease, while the treatment prescribed for the controller as previously explained consists in wiping the copper contact with a rag with a little vaseline.

The oils and grease used should in all cases be of good quality, free from acid and grit. If dirt works into any of the bearings, they should be washed out thoroughly in gasoline or kerosene, the old lubricant discarded and uncontaminated used for repacking.

Adjustments are required from time to time, to tighten nuts or screws, chains, brakes, etc., and may be readily made by inspection of the assembly of the parts, with the aid of the instructions of the manufacturer of the particular machine in question. These minor adjustments are practically all that will be required in normal service, barring accident, except for the yearly overhauling which should be done by a competent mechanic familiar with motor vehicle construction.

The object of the yearly overhauling is to renew such parts as may be necessary, such as chains, sprockets, gears, bearings, etc., and submit all parts to examination so that those badly worn may be replaced before an opportunity for breakdown is given. Arrangements should be made for giving this attention as indicated since, with proper care, the vehicle will not fail to give satisfactory service year after year.

It is the intention in the following paragraphs to give a number of hints which have been found useful in the upkeep of the chassis and in rendering its operation continuous.

Steering Gear. The parts of the steering mechanism require proper lubrication, and oil and grease cups are supplied at points conveniently located for effecting the most satisfactory lubrication and ease of access to the operator. These should be gone over daily and the oil and grease cups attended to.

The pinion and sector must be well lubricated with heavy grease. There are many designs of connection between the drag link, the steering arms

and the cross bar, but construction will readily indicate the proper method of lubricating the wearing parts. These should be cared for daily. All nuts and joints should be kept in good adjustment to prevent play, as a little lost motion on the steering arms would be magnified many times before reaching the steering wheel.

It has been found, that, if the distance between the rims at the front is from 1/8" to 3/16" less than the distance measured between the rims across the rear, the steering will be very much easier, and there will be less tendency for the wheels to depart from a straight line of travel. This toeing in of the front wheels is often called gather. It is important also that, except for the toe in, the wheels run in perfect alignment, as, otherwise, there would be a considerable grinding action upon the tire, which would wear it out rapidly. The adjustment for gather is made by shortening the length of the tie rod between the steering arms. Any nuts which have been loosened to make adjustment should be tightened up securely so that they may not be worked loose, allowing play.

In addition to the grease cups, which lubricate the steering gear proper, it is a good plan to lift the covers, remove the grease and replenish about once every three months.

Chains and Sprockets. Chains and sprockets require both adjustment and lubrication. Under the head of adjustment may be classed the proper alignment of the sprockets. The front and rear sprockets must run in perfect alignment at all times,

as otherwise the teeth of the sprockets would be damaged and the chains made defective. The chains should run with proper tension so that there is sufficient slack when running that they do not run hard or stretch. They must not be too loose, or they may jump off or slap. The distance or radius rods are provided with means for varying the tension. After altering the distance between sprocket centers by the adjustments of the radius rods, lock nuts, if they are used, should be tightened securely so that the adjustment will be permanent. Sprockets, as a rule, do not last as long as the chains. The wear is evidenced by the teeth becoming hook shaped and causing a whipping or snapping of the chain. This condition naturally imposes unnecessary strain on the latter, and should be avoided.

It is practicable to change the sprockets from side to side of the car, thereby making use of both sides of the sets of teeth. Obviously, when both sets have been worn sufficiently, then new sprockets should be installed. New chains should not be used upon old or much worn sprockets for the reasons explained above.

Chains should be kept in good condition by frequent inspection to see that the lengths of the chains on both sides are equal, in order to prevent the rear wheels running out of line. The same number of links must be employed in both chains, and badly worn parts should not be allowed to run for any length of time as they will eventually ruin the entire chain. When a rivet or bushing has become loosened from the side plate from some un-

usual strain, it should be replaced by a new link. Some roller chains are composed of links joined in such a way that each link may be removed without affecting the others, but a great number of chains cannot be dealt with in such a manner, it being difficult to separate the links. The latter type of chain is furnished with a master link, which is serrated at the top edge and has pins a trifle smaller than the others throughout the chain. It is intended for simple and quick removal or replacement. In this type of chain, if it is necessary to replace a worn link, it may be done by inserting a master link.

The lubrication of the chains and sprockets is important and in many cases is practiced in an erroneous manner, namely, by smearing the bearing surface of the chain with grease or oil, which gradually collects dust and grit and causes excessive wear between the rolls and the sprocket teeth. It furnishes no lubrication between the rolls and bushings of the chain, where it is needed most. The following method has been found successful and is recommended by the leading manufacturers:

As often as necessary, such as periods of a month or less, the chain should be removed and soaked over night in kerosene, after which it should be brushed thoroughly and washed with gasoline to remove any adhering particles of gummed oil or rust. After careful inspection and replacement of worn parts, a shallow pan should be used for containing a heavy melted lubricant in which the entire chain should be submerged. The temperature

of the mixture should not be sufficient to draw the temper of the steel, but high enough so that the oil will find its way between the bushings and the rolls or rivets of the chain. Mixtures for this purpose are made up and sold prepared, or a mixture of beef tallow with a small quantity of heavy oil and powdered graphite may be used. In this way the lubricant will penetrate to all parts of the chain. The outside surfaces of the chain should then be wiped dry and the chain may then be replaced and adjusted to the proper tension on the sprockets. It is permissible to apply a light graphite lubricant on the outside of the chain from time to time so that the surfaces of the rolls may run freely over the teeth of the sprockets. Only a small quantity of material should be used for this purpose so that dust and grit may not be collected.

Silent Chains. Silent or link belt chains are usually run completely enclosed in oil when employed in vehicle construction in order that they may be well lubricated at all times and maintained free of dirt. They require very little attention, except for adjustment, after the first 350 or 400 miles and thereafter approximately every 500 miles. A silent chain operates best when it runs slightly looser than would be correct for a leather belt. The lubricant used should be a medium bodied oil of good quality. The joints of the enclosing case should be packed so that the enclosure is tight and does not drop oil.

Countershaft. The countershafts are supported from the frame and have means, such as ball joints

or swivel connections with the distance rods, for maintaining the proper relation with the rear axle construction. Adjustments are provided for keeping the shaft properly lined up. Provisions for oiling and grease cups are supplied where there is opportunity for wear, and care should be exercised in oiling and turning up the grease cups daily.

If a brake drum is provided in connection with the countershaft construction, the brake arrangement should be inspected regularly and any loose or worn parts tightened or replaced.

Differential. The differential gear is lubricated by medium bodied grease supplied in the manner adopted in the make of vehicle under consideration, such as by grease cup, or by removing the cover of the housing and filling the lower portion with a sufficient quantity of lubricant. In winter time it will probably be found necessary to supplement the application of grease with a medium bodied oil to secure the proper lubricating quality. Under conditions of unusual commercial service, it is good practice to take down the differential housing every six months, remove the old grease, clean the parts, and replenish with fresh lubricant of the proper consistency.

Bearings. As explained in the description of the various parts of the chassis, it will be noted that every effort is made to reduce the effect of friction between the working surfaces by the use of anti-friction bearings. With the idea of maintenance in mind, bearings may be divided into two classes, adjustable and non-adjustable. The latter

require lubrication in small quantities and do not permit of adjustment for wear. To prevent side play after they have been in use for a time, thin spacing washers may be secured from the manufacturer which may be placed between the bearings and the moving parts. For sprockets on countershafts a sufficient number of washers may be added so that, when the nuts at the end are drawn up tight, the shaft turns hard. Then one washer should be removed and the nut again brought into position, when the shaft should be lined up properly and run freely with very little play.

Front and rear wheel bearings support the entire weight load and vehicle, and must be kept in perfect adjustment and well lubricated. The adjustment consists in having the wheel drawn up on the spindle tight enough so that very little play is felt but allowing wheel to run free. This is usually accomplished by turning up the axle nut until, by grasping two spokes, one at the top and one beneath the hub, no shake can be felt. The nut may then be backed off a half turn and securely locked to prevent its changing position or coming off the spindle. If there is too much shake, the adjusting nut should be tightened, or, if too tight, preventing the wheel from turning freely, then loosened accordingly.

The motor bearings, as well as those on the wheels and countershafts, are properly adjusted before shipment from the factory and, under normal conditions, will require cleaning in gasoline and repacking with non-fluid oil only, approximately,

every three months to maintain satisfactory operation. Naturally the class of service in which the vehicle is used determines the length of the period between adjustments and thorough overhauling of the wearing parts. Pleasure cars, which are used for only a few miles daily, and heavy trucks, which are driven to their maximum capacity each day in the year, are obviously not in the same class, and so common sense must be made a part of the adjusting and overhauling instructions.

Greases and oils of the best quality without acid or alkaline reaction should be used. Wheel bearings of the roller type should be lubricated by spreading the grease upon the cage holding the rollers. In fact, the hub should be filled with grease which will be taken up by the parts when put into operation, although, at first, it may seem to be excessive. A light grease is suitable for roller bearings.

Bearings in the gear cases, either on countershaft or rear axle, are supplied by means of grease cups, which should be filled regularly once a week and turned down daily.

Springs. Oil cups and grease cups are provided at the points on the springs where friction takes place, and small quantities of oil should be applied and the grease cups given a turn daily. This will prevent bolts and bushings from grinding and wearing out quickly.

The clips should be tightened so that the spring stands firmly on the seat without play. Prominent spring makers recommend inserting a layer of can-

vas steeped in linseed oil and white lead as an excellent packing to be placed between the spring and its seat on the axle. The same authority discourages the use of wood, paper, fibre or leather for this purpose as being more harmful than beneficial. The clips may be taken up at the end of the first and second week of running with full load on, and thereafter at the end of a period of about three months.

Very often friction between the leaves gives rise to disagreeable squeaks and grinding sounds. This may be obviated by lubricating the surfaces between the leaves, by prying them apart and inserting light grease or oil. In performing this operation, care should be taken not to damage the leaf joints. The most satisfactory method recommended by experienced spring makers is to remove the springs from the car about once a year and to disassemble the leaves, washing them in kerosene or turpentine. After boiling in a mixture of tallow and graphite for a few minutes, they may be allowed to dry and be reassembled, sprinkling a small quantity of flake graphite between the leaves. It is said that this treatment will prevent rust for over a period of a year.

Brakes. The braking mechanism requires frequent inspection and adjustment so that there may be no danger of failure at the crucial moment. The care as a rule consists simply in seeing that the normal pressure on the brake pedal produces a firm retarding action. This should be done daily before removing the car from the garage so that, if ad

justments are necessary, they may be made before starting out. If the brakes do not hold, inspection will usually show the method of turning up on the turnbuckle or cam springs, for tightening. It sometimes happens that the full travel of the pedal produces sufficient pressure but there is slip between the shoe and drum. This may be due to oil or grease working its way onto the surfaces. It should be washed out thoroughly with gasoline.

Although the adjustments should be made so that the shoes hold tightly, care should be given that the brakes do not bind or drag. They should take hold gradually and bring the car to an easy stop, except in emergency use, as a sudden locking of the brakes may cause stripped tires, skidding or other damage.

In many vehicles the brake pedal is connected with a rod running transversely, suspended from the frame, so that the pressure applied to the brake pedal may be equalized and distributed evenly to the brakes by means of this equalizing bar. Adjustments are provided so that the action of the rods to the brake shoes may be altered, giving equal retardation on each side of the car. This will be very helpful in preventing skidding.

Dragging brakes not only cause unnecessary wear of the brake lining but use up power, thereby reducing speed and mileage. The shoes should ride about 1/8" free of the drums when the pedal is in the "off" position to prevent any such trouble. Brakes furnished with ratchet locks should be released before the car is started. Some vehicles are furnished

with automatic switches which open the circuit when the brakes are locked; others have a bell ringing contact to indicate that both power and brakes

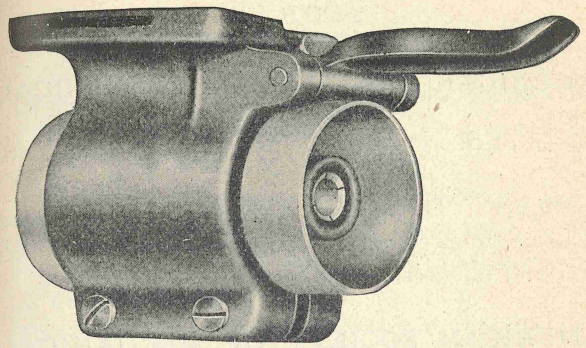


Fig. 161—Standardized Charging Receptacle.

are operative, but differences of opinion exist as to the relative advantages of these means of securing fool-proof construction.

CHAPTER XII.

ASSOCIATIONS AND PUBLICATIONS IDENTIFIED WITH THE DEVELOPMENT OF THE ELECTRIC VEHICLE.

ASSOCIATIONS.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Office of Secretary, 29 West 39th St., New York City.

Object: The advancement of the theory and practice of electrical engineering and of the allied arts and sciences.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Office of Secretary, 29 West 39th St., New York City.

Object: To promote the arts and sciences connected with engineering and mechanical construction.

ASSOCIATION OF AUTOMOBILE MANUFACTURERS.

(Merged into Automobile Chamber of Commerce See below.)

ASSOCIATION OF EDISON ILLUMINATING COMPANIES.

Office of Secretary, 130 E. 15th St., New York City.

Object: Mutual protection of business interests and the collection and dissemination among its

members of technical and business information relative to the Edison electric lighting systems and auxiliary systems operated in connection therewith.

AMERICAN AUTOMOBILE ASSOCIATION.

Office of Secretary, 437 5th Ave., New York City.

Object: To unite in one body all the automobile clubs and individual motorists of the country to secure reasonable and just legislation.

To aid in proper enforcement of automobile laws and ordinances; to advocate and obtain local, State and Federal aid in the construction and maintenance of good roads.

To encourage touring and to secure, prepare and disseminate information relative thereto; and

To support sportsmanlike contests and other movements that will advance motoring interests.

AUTOMOBILE CLUB OF AMERICA.

Office of Secretary, 247 West 54th St., New York City.

Object: To encourage and develop the automobile, motor boat and aerial navigation movement in America.

To provide a centre of information and advice on all matters pertaining to automobiling, motor boating and aeronautics.

To promote original investigation in the mechanical development in this country of the automobile, the automobile engine, as well as the gas engine and other engines for automobiles, boats, flying ma-

chines, and of all forms of mechanism incidental to the propulsion thereof and to the propulsion of boats and flying machines, or related to the sciences of navigation and aviation.

To co-operate in securing rational legislation and rules governing and regulating the use of automobiles in city and country.

To aid in the enforcement of regulations for the public safety.

To protect its members and support them in the defense of their rights, and to protect the interests of owners and users of automobiles, motor boats and flying machines against unjust or unreasonable legislation, and to maintain the lawful rights and privileges of owners or users of all forms of self-propelled pleasure vehicles whenever and wherever such rights and privileges are menaced.

To encourage the construction of good roads and their maintenance, and the improvement of the public highways.

To provide a social club for its members.

AUTOMOBILE CHAMBER OF COMMERCE.

Office of Secretary, 7 East 42nd St., New York City.

Object: To foster the interests of those engaged in the trade or business of manufacturing automobiles and all other self-propelled vehicles. To reform abuses relative thereto. To secure freedom of its members from unjust or unlawful exactions. To diffuse accurate and reliable information as to the standing of merchants and others

dealing with members, as to all inventions, patents, processes or devices designed or intended for use in, upon, or in connection with such vehicles and the manufacture thereof, as to the state of the art relative thereto, and as to the condition and development of the trade in which the members are engaged, in the United States and foreign countries. To procure uniformity and certainty in the customs and usages of such trade.

To promote the construction of better highways. To advocate enactment of just and equitable laws affecting members. To settle differences between members. To promote a more enlarged and friendly intercourse among business men engaged in such trade or dealing with persons engaged therein.

To acquire, by grant, gift, purchase, device or bequest, to hold and to dispose of such property as the purposes of the corporation shall require, subject to such limitations as may be prescribed by law, including inventions, letters patent and processes, or rights thereunder, for the benefit of its members and not for pecuniary profit.

AUTOMOBILE TRADE CREDIT ASSOCIATION.

Office of Secretary, 80 Wall St., New York City.

Object: To protect members against irresponsible debtors; collect and disseminate credit information.

ELECTRIC VEHICLE ASSOCIATION OF AMERICA.

Office of Secretary, 29 West 39th St., New York City.

Sections: Chicago, Cincinnati, Cleveland, Denver, Detroit, Los Angeles, New England, New York, Philadelphia, Pittsburg, St. Louis, San Francisco, Toronto, and Washington.

Object: To promote the adoption and use of electric vehicles for business and pleasure purposes.

Official Organ: "The Central Station," published monthly at 53 Park Row, New York City.

ELECTRIC MOTOR CAR CLUB OF BOSTON.

Office of Secretary, 39 Boylston St., Boston.

Object: To promote the adoption and use of electric motor cars for business and pleasure purposes.

ELECTRIC AUTOMOBILE MANUFACTURERS' ASSOCIATION.

Secretary's Office, Chicago, Illinois.

Object: The object of the Association shall be the betterment of the Electric Automobile Industry.

MOTOR AND ACCESSORY MANUFACTURERS, THE.

Office of Secretary, 17 West 42nd St., New York City.

Object: To promote in all lawful ways the interests of makers of motors, motor parts, and accessories. To aid in the protection of its members. To secure the advantages to be obtained by mutual co-operation. To facilitate the collection of the claims of its members and the diffusion of information concerning trade, dealers, credits, and other matters of interest to the members of the association. To co-operate with similar associations in other States.

MOTOR TRUCK CLUB OF AMERICA.

Office of Secretary, 1790 Broadway, New York City.

Object: To advance the interests of the motor truck industry and to promote and further the use of motor vehicles.

NATIONAL ELECTRIC LIGHT ASSOCIATION.

Office of Secretary, 29 West 39th St., New York City.

Object: To foster and protect the interests of those engaged in the commercial production of electricity for conversion into light, heat or power.

SOCIETY OF AUTOMOBILE ENGINEERS.

Office of Secretary, 1790 Broadway, New York City.

Object: To promote the arts and sciences connected with engineering and mechanical construction of automobile vehicles.

NEW YORK ELECTRIC VEHICLE ASSOCIATION.

Office of Secretary, 130 E. 15th St., New York City.

Object: To promote, introduce and accelerate the use and distribution of electric vehicles.

SOCIETY FOR ELECTRICAL DEVELOPMENT, INC.

Office of Secretary, 29 West 39th St., New York City.

Object: To promote and increase the use by the public of electric current for all useful purposes as an end in itself and as a means for increasing the demand for apparatus and supplies; and to promote and facilitate a co-operative planning and execution of various means and methods effective to this end; to encourage and promote the development of the electrical science, art and industry, both technical and commercial; to develop means and methods tending to promote the welfare of individuals identified with all branches of said business; to encourage harmonious relations which will assist in maintaining the industry in the highest confidence of the public; to establish co-operative relations among the different electrical interests, from manufacturer to consumer, to the end that

each may contribute in some measure toward bringing about the aforesaid results desired by all.

TOURING CLUB OF AMERICA.

Office of Secretary, Broadway and 76th St., New York City.

Object: To enhance the delight and popularity of motor touring in every possible way.

PUBLICATIONS.

Accessory & Garage Journal, Pawtucket, R. I.

American Motorist, 437 5th Ave., New York City.

Auto Dealer & Repairer, 71 Murray St., New York City.

Automobile, The, 239 West 39th St., New York City.

Automobile Blue Book, Broadway and 76th St., New York City.

Automobile Journal, Pawtucket, R. I.

Automobile Topics, 1790 Broadway, New York City.

Automobile Trade Journal, Philadelphia, Pa.

Central Station, Pulitzer Building, New York City.

Commercial Car Journal, Market and 49th Sts., Philadelphia, Pa.

Commercial Vehicle, The, 231 West 39th street, New York City.

Edison Monthly, 55 Duane St., New York City.

Electrical Engineering, Grant Building, Atlanta, Ga.

Electrical News, Toronto, Ont.

Electrical Record, 114 Liberty St., New York City.

Electrical Review & Western Electrician, 13 Park Row, New York City.

Electrical World, 239 West 39th St., New York City.

Electric Vehicles, Monadnock Building, Chicago.

Horseless Age, 244 West 54th St., New York City.

Motor, 381 4th Ave., New York City.

Motor Age, 239 West 39th St., New York City.

Motor Car, New York City.

Motor Field, Denver Colo.

Motoring, Toronto, Ont.

Motoring, Indianapolis, Ind.

Motorist, The, 606 Bee Building, Omaha, Neb.

Motor Life, 337 West 38th St., New York City.

Motor Magazine, Toronto, Ont.

Motor Print, Philadelphia, Pa.

Motor Truck, Pawtucket, R. I.

Motor World, 1600 Broadway, New York City.

Pacific Motor & American Motor News, San Francisco, Cal.

Popular Electricity, Chicago, Ill.

Power Wagon, 322 Michigan Ave., Chicago.

Practical Electricity & Engineering, Chicago, Ill.

Scientific American, 31 Broadway, New York City.

Selling Electricity, 17 Madison Ave., New York City.

Southern Motoring, Dallas, Texas.

Western Motor Record, San Francisco, Cal.

Wisconsin Motorist, Milwaukee, Wis.

CHAPTER XIII.

COMPARATIVE COST DATA

Electric commercial vehicles are displacing the horse in more than one hundred lines of business. The changes have neither been sudden nor without deliberate study. Many of the larger installations of today are those which were started ten to twelve years ago experimentally. The nucleus of one or two trucks has gradually expanded into fleets which in many cases exceed a hundred vehicles.

This steady, conservative adoption by the largest and most skillfully managed companies in practically every industry is sufficient argument for the general introduction of machine operation.

The operation of horse-drawn vehicles has been the standard method hitherto, and it is within reason to understand that the change from animal to machine power is not and will not be one of meteoric rapidity. There must be a revolution in methods, however, and just such a change is taking place now. The progressive forces of efficiency are making conquests of ultra-conservatism and inertia in no half way fashion.

There are two methods of arriving at definite conclusions concerning the advantages of motor over horse-drawn vehicles. The first is to try them out side by side, keeping accurate records and analyzing the results. This takes time and in a great many cases is unnecessary where reliable data of operations under similar conditions is available. This brings us to the second method, which

is constructive rather than experimental, and consists in applying the knowledge gained from carefully studied performances to the proposed cases. In order to carry out such study, it is necessary to have at hand reports of tests and records of operation covering periods of considerable length of time. Such data must include all the items of cost, and must also be detailed sufficiently to permit of a careful study of the factors which govern the final results.

There is unfortunately a lack of information on the cost of animal transportation; few indeed are the individuals or corporations using this means of haulage who have accurate cost data. In practically all installations it is a saving of dollars and cents that the introduction of power wagons will effect, but it is difficult to show, clearly and conclusively, the extent of the gain unless the figures of horse operation are at hand. In most cases they are not, so that perfectly correct and authentic recommendations are unfairly discounted to the mutual disadvantage of those concerned.

Most of the electric vehicle manufacturers are prepared to make exhaustive studies through their experts, of the transportation problems in any individual case and to submit to the prospective purchaser comprehensive reports covering the details of the proposed service.

The services of a number of consulting engineers, specializing in transportation engineering, are available for the solution of problems of this nature.

The investigations preliminary to the adoption of

large machine delivery installations are usually conducted by experts of either of these classes.

This chapter is written with the intention of throwing some light on the oft-repeated question, "How much will it cost to run?" To answer this query for each case could well dispose of the contents of several volumes, and even then not do justice to the subject. However, a general answer is possible by giving either typical cases or average data, supplemented with comments on the variable elements which govern the final results. It must be remembered that each transportation department has features which are peculiar to it and to the city in which it is located. These variables naturally make the total costs higher or lower than the average, so that a given set of figures should not be taken to apply directly without correction to the individual case under consideration.

In order to place reliable data pertaining to horse and electric haulage costs before the public, a careful investigation has been carried out by the Research Division of the Electrical Engineering Department, Massachusetts Institute of Technology, for the purpose of securing and collecting the records covering transportation performances in every industry in the larger cities of the East. This information, collected by means of the record form (Report of Electric Truck Operation). Table 19, page 343, and personal investigation, has been published from time to time. The tables 13-17 of this chapter are taken from this study as being indicative of average performances.

TABLE 13.

1,000 lb. Rating

ESTIMATE FOR PARCEL DELIVERY

Average maximum load, approximate	1,000 lbs.	Hours per trip for loading.	1.0
Mileage per trip	12	Minutes per delivery	0.9
Deliveries per mile	6	Minutes per stop	1.8
Deliveries per stop	2	Hours working per day	9.0

VEHICLE.	1,000 lb. Electric.	1 Horse Wagon, ½ Extra Horse.
Average running speed	9.5	5
Hours per trip, standing	2.1	2.1
Hours per trip, moving	1.2	2.4
Hours per trip, total	3.3	4.5
Average number of trips per 9 hour day	2.7	2.0
Miles per day	33	24
Deliveries per day	198	144
Days used per year	285	285
Miles per year	9,400	68,000
Deliveries per year	56,500	41,000
EXPENSE, ANNUAL:		
Tire or shoeing, etc	$150	$54
Repairs	270	125
Battery	225	.....
Veterinary	.....	9
Lubricants	15	.....
Electricity at 3c per kw. hr	145	.....
Feed	.....	290
Garage or stable	200	110
Driver and helper	1,000	1,000
Depreciation	165	160
Interest	60	24
Insurance	135	30
Total Annual Expense	$2,365	$1,812
Cost per day	$8.30	$6.40
Cost per delivery	4.02	4.05
Cost per mile	.25	.27

SUMMARY

Value in Cents per Mile.	Electric.	Horse.
Electricity or feed	1.5	4.3
Maintenance	7.0	2.8
Storage, driver and helper	12.7	16.3
Overhead charges	3.8	3.1
Total	25.0	26.5

TABLE 14.

1 Ton Rating.†

ESTIMATE FOR CITY BAGGAGE DELIVERY

Average maximum load, approximate	2,000 lbs.	Deliveries (or collections), per stop	1
Miles per trip	10	Hours at station per trip	0.5
Deliveries (or collections), per mile	1	Minutes per stop	7
		Hours working per day	9

VEHICLE.	2,000 lb. Electric.	1 Horse Wagon, (1 Extra Horse).
Average running speed, miles per hour	9	5
Hours per trip, standing	1.7	1.7
Hours per trip, moving	1.1	2.0
Hours per trip, total	2.8	3.7
Average No. of trips per 9 hour day	3.2	2.4
Miles per day	32	24
Deliveries per day	32	24
Days used per year	310*	310*
Miles per year	10,000	7,500
Deliveries per year	10,000	7,500
EXPENSE PER YEAR:		
Tires or shoeing	$175	$72
Repairs	290	125
Battery	270	.....
Veterinary	.....	12
Lubricants	15	.....
Electricity at 3c per kw. hr.	180	.....
Feed	.....	380
Garage or stable	200	150
Driver and helper	1,240	1,240
Depreciation	225	170
Interest	75	26
Insurance	160	35
Total Annual Expense	$2,830	$2,210
Cost per day	9.10	7.10
Cost per mile	.28	.30
Cost per delivery	.28	.30

*Wagons considered to work on alternate Sundays.

SUMMARY

Value in Cents per Mile.	Electric.	Horse.
Electricity or feed	1.8	5.2
Maintenance	7.5	3.0
Storage, driver and helper	14.4	18.6
Overhead Charges	4.6	3.2
Total	28.3	30.0

†Table by Mr. H. F. Thomson, Research Division, M. I. T.

TABLE 15.

2 Ton Rating.

ESTIMATE FOR FURNITURE DELIVERY

Average maximum load, approximately .....4,000 lbs.	Hours per trip for loading... 0.7
Mileage per trip..... 12	Minutes per call..... 6.
Calls per mile..... 1	Hours working per day..... 9.

VEHICLE.	4,000 lb. Electric.	2 Horse Wagon, 1 Extra Horse.
Average running speed, miles per hour.....	8	5
Hours per trip, standing.....	1.9	1.9
Hours per trip, moving.....	1.5	2.4
Hours per trip, total.....	3.4	4.3
Average number trips per 9 hour day.....	2.65	2.1
Miles per day	32	25
Calls per day	32	25
Days used per year.....	285	285
Vehicles, miles per year.....	9,100	7,150
Calls per year	9,100	7,150
EXPENSE, ANNUAL:		
Tires or shoeing, etc.....	$225	$108
Repairs	260	125
Battery	270	.....
Veterinary	.....	18
Lubricants	15	.....
Electricity at 3c per kw. hr.....	200	.....
Feed	.....	570
Garage or stable.....	220	220
Driver and helper.....	1,140	1,140
Depreciation	240	210
Interest	84	31
Insurance	140	35
Total Annual Expense.....	$2,794	$2,457
Cost per day.....	9.75	8.60
Cost per call	.31	.35
Cost per mile	.31	.35

SUMMARY

Value in Cents per Mile.	Electric.	Horse.
Electricity or feed.....	2.2	8.0
Maintenance	8.5	3.5
Storage, driver and helper.....	14.9	19.1
Overhead charges	5.1	5.0
Total	30.7	34.6

TABLE 16.

3½ Ton Rating.

ESTIMATE FOR KEG BEER DELIVERY

Average maximum load, approximate .....7,000 lbs.	Hours per trip for load and unload 0.75
Mileage per trip..... 14	Minutes per call..... 8.
Calls per mile..... 0.7	Hours working per day... 9.

VEHICLE.	7,000 lb. Electric.	2 Horse Wagon, 2 Extra Horses.
Average running speed, miles per hour....	7	4
Hours per trip, standing.....	2.1	2.1
Hours per trip, moving.....	2.0	3.5
Hours per trip, total.....	4.1	5.6
Average number of trips per 9 hour day....	2.2	1.6
Miles per day	31	22
Calls per day	22	15
Days used per year.....	285	285
Vehicles, miles per year.....	8,850	6,250
Calls per year	6,200	4,370
EXPENSE, ANNUAL:		
Tires or shoeing, etc.....	$330	$144
Repairs	300	125
Battery	360	.....
Veterinary	.....	24
Lubricants	15	.....
Electricity at 3c per kw. hr.....	265	.....
Feed	.....	760
Garage or stable	240	280
Driver and helper.....	1,210	1,210
Depreciation	290	250
Interest	102	38
Insurance	140	35
Total Annual Expense.....	$3,252	$2,866
Cost per day	11.40	10.00
Cost per call	.52	.66
Cost per mile	.37	.46

SUMMARY

Value in Cents per Mile.	Electric.	Horse.
Electricity or feed.....	6.0	12.2
Maintenance	11.3	4.7
Storage, driver and helper.....	16.4	23.8
Overhead charges	6.0	5.2
Total	36.7	45.9

TABLE 17.

5 Ton Rating.

ESTIMATE FOR COAL DELIVERY

Average maximum load, approximately .....10,000 lbs.
Mileage per trip..... 6
Hours per trip for loading.. 0.2
Hours per trip for unloading 0.7
Hours working per day.... 9.0

VEHICLE.	10,000 lb. Electric.	3 Horse Wagon, 2 Extra Horses.
Average running speed, miles per hour.....	6	3
Hours per trip, standing.....	0.9	0.9
Hours per trip, moving.....	1.0	2.0
Hours per trip, total.....	1.9	2.9
Average number of trips per 9 hour day.....	4.7	3.1
Miles per day	28	18.5
Tons delivered per day.....	23.5	15.5
Days used per year.....	285	285
Vehicle, miles per year.....	8,000	5,300
Tons delivered per year.....	6,700	4,400
EXPENSE, ANNUAL:		
Tires or shoeing, etc.....	$400	$175
Repairs	300	100
Battery	440	.....
Veterinary	.....	30
Lubricants	15	.....
Electricity at 3c per kw. hr.....	290	.....
Feed	.....	900
Garage or stable	270	335
Driver and helper.....	1,210	1,210
Depreciation	400	.....
Interest	135	45
Insurance	150	40
Total Annual Expense.....	$3,610	$3,135
Cost per day	12.30	11.00
Cost per ton delivered	.54	.71
Cost per mile	.45	.59

SUMMARY

Value in Cents per Mile.	Electric.	Horse.
Electricity or feed.....	3.6	17.0
Maintenance	14.4	5.8
Storage, driver and helper.....	18.5	29.2
Overhead charges	8.6	7.3
Total	45.1	59.3

These estimates, based on actual operating data supplemented by itemized costs furnished by many operators, give a broad conservative outline of average conditions. The components are given in the simplest terms so that alterations to suit any case may be readily effected.

The items of loading and unloading, as well as distances between the points of receipt and delivery, agree closely with those obtaining in the large metropolitan districts. The radius of action as indicated in each case has been determined by the requirements of the delivery service.

Inspection of these tables shows in each case the economy of the electric vehicle over the horse-drawn equipment. From this it will be seen that the number of miles covered and deliveries made by the electric truck are sufficiently in excess of those negotiated by the horse to justify the change, without reference to the equally important advantages of time, space, advertising and reliability of service. The statement of economies effected is conservative. The great majority of electric vehicle applications shows the savings to be considerably more than the above.

The column heading of extra horses refers to the average number of horses required to operate the drawn vehicles each working day. This allows for sickness and rest under average conditions, making the bases of comparison fair.

TABLE 18.

COST OF OPERATING SINGLE AND DOUBLE TEAM IN BOSTON

These figures compiled for a company operating 160 horses. *

Drivers' pay per day	$2.00	$2.50
Feed per working horse per day	.90	1.80
Rent and stable expenses per horse per day	.31	.62
Shoeing and small repairs per horse per day	.19	.38
Claims, accidents, tolls, etc	.18	.36
Foreman's and lumber, pro rata	.18	.36
Other helpers per horse per day	.20	.40
Repairs, harnesses and painting	.13	.26
Manager's or superintendent's salary per day	.10	.20
Office rent, telephones and clerks	.31	.62
Miscellaneous, veterinary, etc	.24	.48
Fire and accident insurance	.08	.16
Depreciation for renewals of horses	.20	.40
	$5.02	$8.54

ACCOUNTING

The subject of accounting is a very broad one and presupposes a considerable amount of detail. The purpose of the paragraphs which follow is to indicate methods which experience has shown to be satisfactory rather than to discuss their relative merits. The important principle is to record the data in such form that intelligent study may be applied to all the conditions of operation toward the securing of most efficient and economical results.

A suggested arrangement views all charges in three classes, Overhead, Fixed, and Operating Charges. Overhead Charges embrace Amortization, Interest, Fire and Liability Insurance, and Administration. The Fixed Charges cover General Garage Expense, Garage Labor, Registration of Vehicle and Chauffeur, Driver, Helper and Sundries. The Operating Charges may be divided into

*Compiled by W. H. S. Jarvis, C. P. A.

TABLE 19.

REPORT OF ELECTRIC TRUCK OPERATION.

(Specimen Form for Recording Data.)

Company ..... Business.....

GENERAL INFORMATION.

Rated capacity of truck.
Class of service.
Report covers period from (date).
To (date).
No. of trucks reported.
Investment per truck.
Age of truck.
Company's number of truck.
Battery (size; lead or Edison).
Tires (size; solid or cushion).

PERFORMANCE PER TRUCK.

DURING ENTIRE PERIOD.
Miles traveled.
Kw-hr. consumed.
Days used.
Work days out of commission.

PER DAY.
Miles traveled.
No. of trips.
No. of deliveries.
Weight of loads.

EXPENSE PER TRUCK. Total during entire period.

OPERATING CHARGES.
1. Lubricants.
2. Electricity at——c. per kw-hr.
3. Battery renewals.
4. Tire renewals.
5. Repairs, parts.
6. Repairs, labor.
7. Painting.

FIXED CHARGES.
8. Garage rent and general expense.
9. Garage, labor.
10. Sundries.
11. Driver.
12. Helper.

OVERHEAD CHARGES.

13. Amortization.
14. Interest.
15. Insurance, fire.
16. Insurance, liability.
17. Administration.

COMPANY'S TOTAL EXPENSE.

OPERATING CONDITIONS.

Portion of road surfaces which are paved , macadam , dirt
Level, rolling or hilly territory.
Specific data on per cent. grade and length of grades.
Special road or loading conditions which are not common to other companies in this locality
Practice as to loading truck beyond capacity
Maximum speed which drivers are allowed to attain
Loading Devices.

Remarks:
Note—Data should cover as long a period as possible.

Running Costs and Maintenance Costs, but usually are not. They include Electricity, Battery Renewals, Tire Renewals, Lubricants, Repair Material, Repair Labor, and Painting.

Amortization or Depreciation. In order to provide for a new truck at the end of the useful life of the one entering service, a yearly sum, called either a depreciation or an amortization charge, is generally set aside. The amount of this charge depends upon the cost of the truck and its probable life. Ten years is urged by the vehicle manufacturers as a safe estimate.

The depreciation may be taken as a percentage of the entire first cost, or upon the first cost less the tires and battery elements, both of which are renewed several times within the useful period.

Interest. The item of interest on the investment is the familiar charge and usually is taken at 5% or 6%. In making the interest charge it must be remembered, however, that the amortization charge is not an actual expense, being set aside to earn interest at a rate equal to that charged against the investment. Therefore, the interest should be figured on half the investment at the full rate, or on the whole investment at half the rate.

When the depreciation is charged against the first cost less the tires and battery, then the interest should be figured on these renewable parts separately, and added to the interest on the reduced investment.

Insurance. Fire insurance rates for electric vehicles are lower than those fixed for gasoline cars

as there is considerably less hazard. Liability insurance, covering injury or loss both to the insured or others, is written under several forms of policy, each of which favors the electric vehicle over the gasoline propelled car. The rates differ in various sections of the country, and are subject to change from time to time, the tendency being for substantial reductions.

Administration. This is an item of overhead expense which may or may not be charged directly, but is intended to cover the cost of superintending operation and maintenance. The facilities of the garage and the number of cars handled determine the amount of this expense, which appears to average about $50—$60 per car year.

Fixed Charges. Driver, Helper, Sundries and Registration are items which need little comment as they vary with the local conditions, but are regular charges common to all installations and practically not affected by the number of miles traveled. General garage expense, covering rent and upkeep, as well as garage labor, are variable quantities depending upon the size of the vehicle installation and the locality chosen.

Operating Charges. These figures are influenced almost entirely by the mileage, the nature of the roads, grades, speed and general care.

Painting. Painting and body work cover the cost of keeping up good appearance which is looked upon as a decided asset in many lines of business. In some cases it is felt that the advertising secured by a smart rig is sufficient to pay part of its up-

keep. Although this is seldom charged to an advertising account, it might be done with propriety.

Lubricants. Oils, grease and waste are absolutely necessary to operation, but represent an almost negligible percentage of the total costs of the electric vehicle.

Renewals. There are three vital parts which form the bulk of the renewal expense. These are battery, tires and mechanical parts.

The life of the storage battery depends upon the number of cycles of charge and discharge, or, roughly speaking, upon the mileage traveled as well as upon the application of the proper size for the service and the care received. The last two points mentioned are important as insufficient capacity and lack of the necessary attention go far toward increasing the expenses.

Improved batteries of both lead and alkaline types, with liberal guarantees, make the battery charges very definite and point to lower maintenance cost for these reasons.

Tires. The renewal of tires is one of the important costs. Overloading and abuses of similar nature have a direct bearing on the life of tires. The manufacturers protect their product with guarantees and pursue a liberal policy of adjustment on material which is worn rapidly because of conditions over which neither consumer nor manufacturer has control. Conservative records show that, for the smaller capacity vehicles, 6-10% of the total expense seems to be about the usual charge,

while, in the larger sizes, 15-18% may be looked upon as a fair amount.

Electricity. The rates for electrical energy are different in various localities over the country, depending in every case upon the cost of producing and distributing the energy. In some districts a sliding scale of rates with increased kilowatt-hour consumption is effective while in others a practically uniform rate obtains. Fuel costs, such as for hydrocarbon products, and hay, oats, etc., are steadily, yes rapidly, increasing in price, while any change in the cost of electricity is toward a reduction. The electric car, especially the commercial vehicle, is charged at off-peak hours, arguing well for lower rates to secure this attractive form of load.

The question of fuel cost (electricity) is really not the important one that popular fancy would have it. The cost of electrical energy used to propel the vehicle, as a percentage of the total yearly costs, will seldom exceed 10%, and in a majority of cases, it is nearer 6% of the total costs.

Accounting, Another arrangement contemplates the recording of electric vehicle costs on an annual basis, divided into three divisions: Fixed Charges, Maintenance and Operation. Fixed charges should cover interest and amortization, or those charges which relate to capital investment. Maintenance includes everything necessary for keeping the equipment in operating condition, including the annual charges for upkeeping the working equipment, labor (garage), current, etc., irrespective of the

daily mileage performed, because under actual conditions as they are sometimes found these charges are not proportional to the mileage service rendered. Operation includes only charges for operators, helpers and possibly such other charges essential to the employment of the vehicle in service as do not relate to the vehicle in daily operatable condition.

The items of cost given above include the charges applied in usual operation in all lines of business. The nature of their variation has been outlined so that a proper factor of correction, depending upon the nature of the service, might be applied to the cost estimates in Tables 13-17. The service conditions affecting the costs may be grouped under the heads of load, distance, roads and speed.

Load. The weight of the initial load determines the carrying capacity of the truck to be used, while the bulk of the packages affects the size and shape of body needed for most efficient handling. When packages are to be collected on the return trip, then provision for their size and weight must be made.

It is uneconomical to operate the cars loaded considerably below their capacity, while, on the other hand, overloading as a regular process is to be thoroughly discouraged, because of the excessive wear on tires, battery, etc.

Distance. The radius of operation varies with the distance from the loading point to the center of delivery, the number of trips required per charge of battery, as well as with the number of stops, length of return trip, and road conditions.

The statement is often made that the electric car does not possess the ability to negotiate long distances, but the answer is obvious when it is called to mind that with the time taken for loading, unloading and traffic blocks, mileages in excess of 50-60 miles per day are difficult to accomplish even with high-geared gasoline cars in city and suburban service. It is an accepted fact among unbiased students of transportation problems that the electric is in no way lacking in mileage when used in its proper application.

Roads. Road conditions both as to quality and character of surface affect the wear on tires, current consumption, battery and mechanical parts. Grades are specially effective in increasing the current consumption and cutting down the mileage. These effects do not interfere with satisfactory operation as the battery may be boosted to secure additional mileage. With intelligent handling, the capacity may be thus increased in an economical manner.

Speed. What has been said above in regard to the mileage limitations of the electric applies equally well to those of speed. The number of trips required, with the distances between loading and unloading points, have an important bearing on the time requirements. Balanced against these are the limitations imposed by the time taken for the individual deliveries and speed of the traffic in general. Routing is important in this connection so that not only the idle time may be reduced to a minimum but

TABLE 20.

HEAVY SERVICE*

	No. of Vehicles. Horse.	Machine.	Investment. Horse.	Machine.	Expense. Horse.	Machine.
1	75	44	$94,551	$166,733	$136,746	$113,087
2	30	11	26,615	36,584	44,198	28,378
3	16	5	7,975	17,784	15,587	11,557
	121	60	$129,141	$221,101	$196,531	$152,022
			RELATIVE PROPORTIONS.			
	(1:.5)		(1:1.70)		(1:.77)	

TABLE 21.

MEDIUM SERVICE*

4	35	31	$36,485	$83,003	$91,530	$70,663
5	17	10	14,300	23,500	29,074	18,972
6	33	20	21,848	51,126	50,249	38,444
7	21	14	39,778	46,170	41,593	31,802
8	48	37	54,095	75,598	115,284	75,745
	154	112	$166,506	$279,397	$327,730	$235,626
			RELATIVE PROPORTIONS.			
	(1:.72)		(1:1.67)		(1:.72)	

TABLE 22.

SUMMARY OF TABLES 21 AND 22.

No.	Annual Saving.	Earnings in Per Cent. of the Investment.	Saving over Horse Expense in Per Cent.
1	$23,660	14.2	17.5
2	15,819	43.2	35.7
3	4,030	22.6	25.8
	$43,509	19.6	22
4	$20,867	25	23.5
5	10,102	42.9	34
6	11,805	23	23
7	9,791	21.2	23.3
8	39,539	52.3	34.2
	$92,104	32.9	28

that time consumed in reaching the beginning of the deliveries may be reduced.

It is possible to give high speed or great mileage in electric vehicles, as record of a mile in 42 seconds, or 244 miles on one battery charge, indicate. Neither of these qualities are desired to such an extent, however, for the solution of transportation problems by means of delivery machinery.

Summary. In the foregoing pages, with tables of data, the aim has been to present the components of operating costs with the variable factors which influence the preliminary and final results. Little space has been devoted to the purpose of showing the superiority of machine transportation over animal means as it has been felt that an exposition of the modern methods would be more appreciated at this time.

The information given in Tables 21 and 22 above is particularly apropos as it represents the results accomplished by five of the largest Department Stores in the country.

The savings indicated are not unusual. Such economies are characteristic of the large installations, which are becoming more numerous in a manner thoroughly encouraging to their advocates. The general introduction of the power wagon, which for city and suburban service is the electric vehicle, admits of proportionate economy to the establishment in which a single car constitutes the transportation equipment.

* Paper by Mr. W. P. Kennedy, read before the National Association Automobile Manufacturers.

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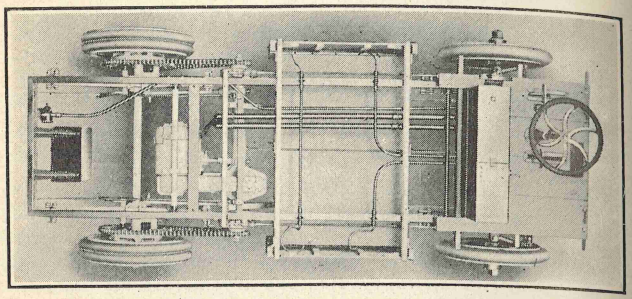

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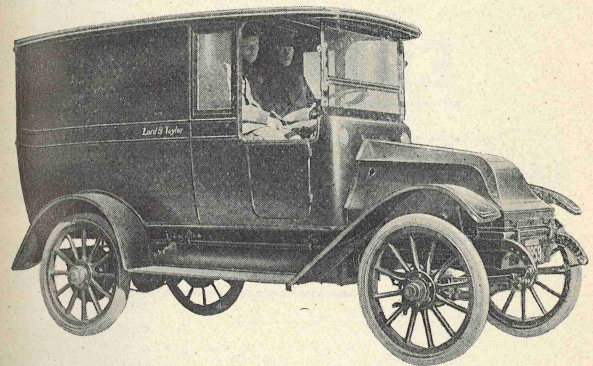

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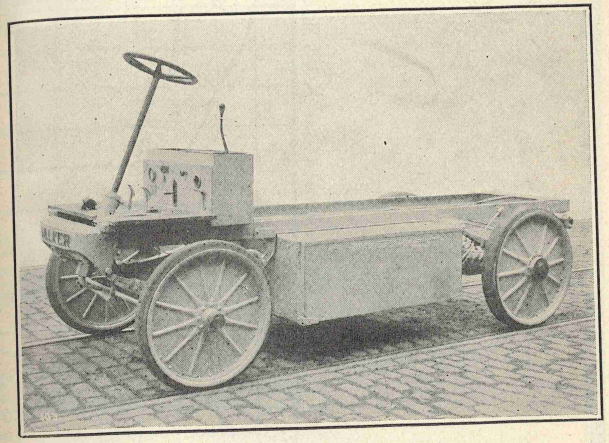

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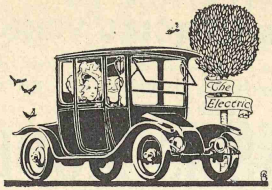

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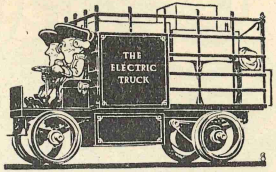

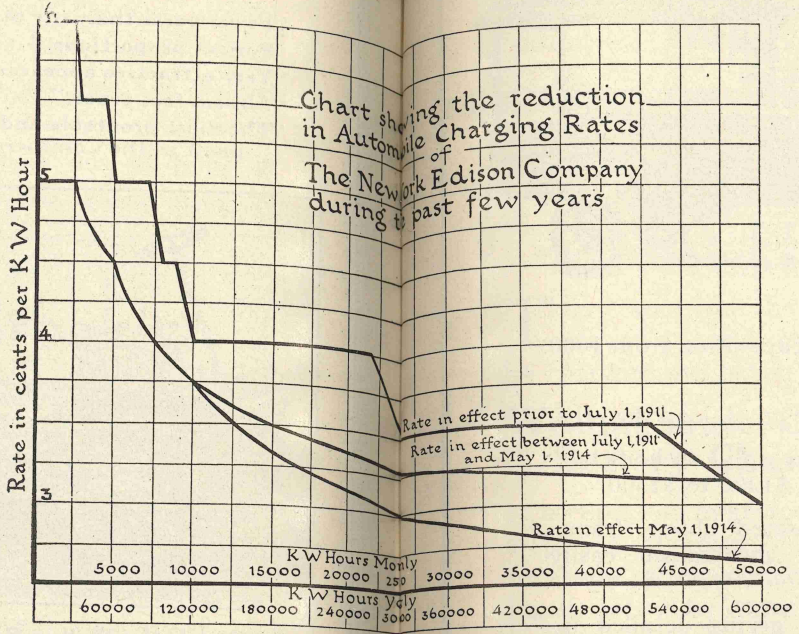

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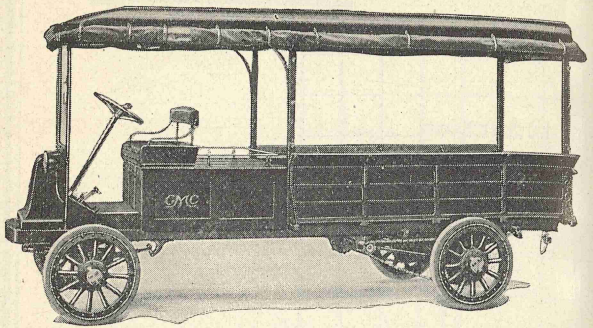

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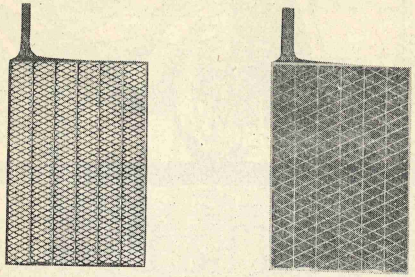

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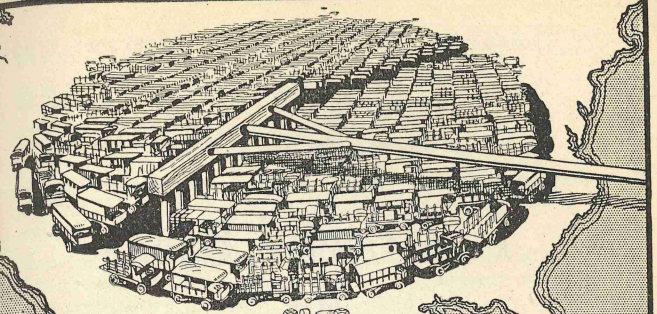

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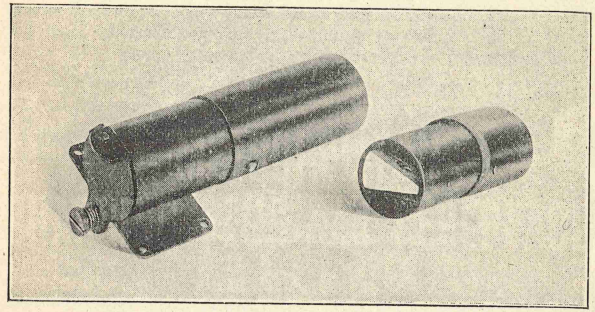

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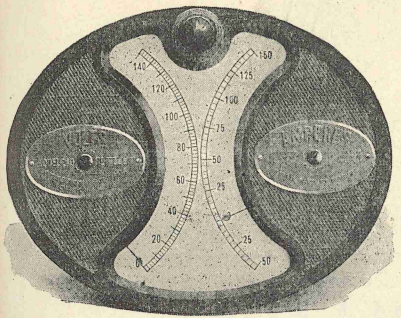

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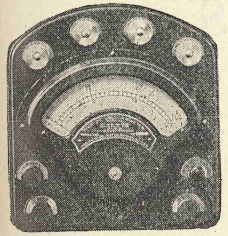

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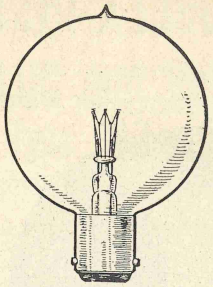

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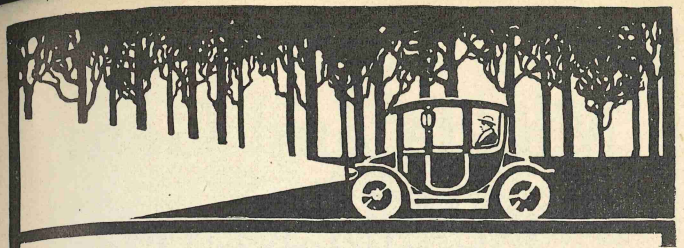

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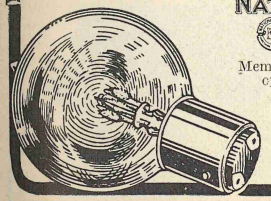

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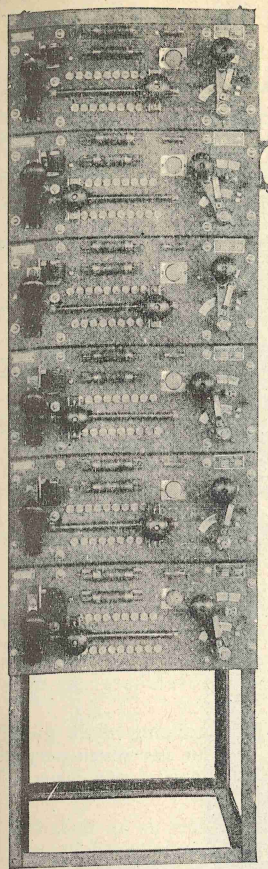

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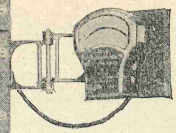


The new Cutler-Hammer charging panel with self-contained rheostat units is assembled like the present day efficient filing cabinet.

CUTLER-HAMMER Unit Type Battery Charging Panels

can be made up in frames containing any number of charging rheostats. This arrangement is as elastic as the unit type sectional filing cabinets. The sections are only 10 inches high by 24 inches wide by 20 inches deep. A section can be easily removed, inspected or replaced.

ALLOW FOR GROWTH

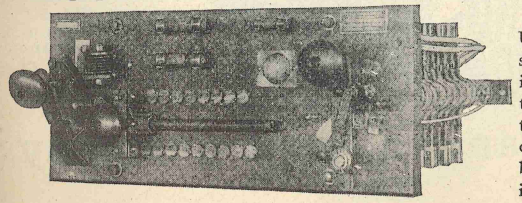
Unit type panels take care of the future,—standard units can be added whenever necessary, which eliminates the necessity for expensive changes. They are suited to the small, the large and the growing garage,—for use on both two-wire and three-wire circuits.

Booklet containing Battery Charging Equipment Bulletins sent on request. Address nearest office.

THE CUTLER-HAMMER MFG. CO.

MILWAUKEE, WIS.

New York, Chicago, Pittsburg, Boston, Cleveland, Cincinnati, Philadelphia.



Unit charging section, which is the basis of the new sectional bookcase idea in battery charging panels.

SOME ADVANTAGES OF

Ampere-Hour Meters

used in connection with **Electric Vehicles**

1. Exact condition of battery with respect to charge shown at all times; that is, amount of electricity taken out and useful amount remaining.
2. Equally suitable for lead or Edison batteries.
3. Operation not affected by temperature, age of battery, condition of electrolyte or other factors seriously affecting readings of voltmeter.
4. Provide absolute, positive automatic method of giving battery correct amount of charge, not possible in any other way.
5. With contact at full charge point on dial—in connection with circuit breaker—a certain and correct method of cutting off charge automatically, without attention of operator is provided.
6. By giving correct percentage of overcharge, they eliminate serious overcharge and consequent reduction in battery life often found in charging by other methods.
7. By showing operator amount discharged at any time, they prevent discharge to exhaustion and consequent tendency to injure battery by sulphation of plates.
8. They provide simple and direct means of giving battery desired amount of periodical overcharge at definite intervals.
9. Commercial service meter with totalizing dials gives direct record of total current used in any given period for operation of vehicle, thus giving cost per car-mile or ton-mile.
10. In general, the amperehour meter acts as an unfailing "watch dog of the battery," and can be used by persons entirely unfamiliar with characteristics of storage batteries, which the voltmeter and ammeter cannot.

SANGAMO

Write for details of our new "M. S." (Miniature) type Sangamo Amperehour Meter. Especially adapted where the consideration of space and the cost of the meter are paramount.

For full description see pages 190-209.

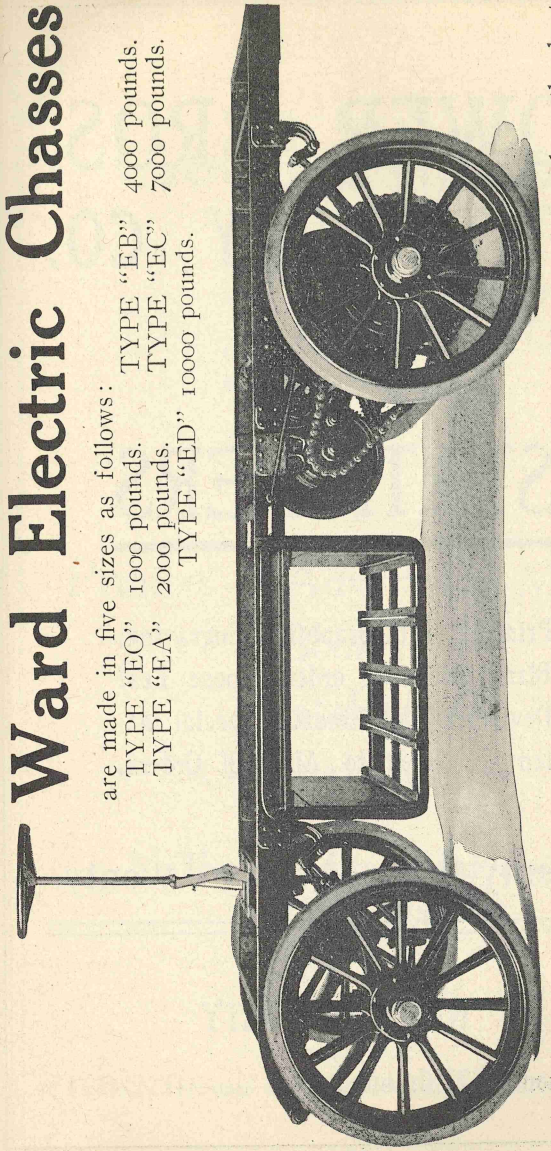
Sangamo Electric Company

Springfield, Illinois

Ward Electric Chasses

are made in five sizes as follows:

TYPE "EO" 1000 pounds.
TYPE "EA" 2000 pounds.
TYPE "EB" 4000 pounds.
TYPE "EC" 7000 pounds.
TYPE "ED" 10000 pounds.



More than ten years of experience in this line of work qualifies us to produce the best. Uniform designs, uniform prices and maximum value are links in our chain of success.

Prices, photographs and general information furnished on request.

WARD MOTOR VEHICLE COMPANY, New York

TOWER BROS. STATIONERY CO.

Wholesale, Retail
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Printing, Lithographing, Engraving, Blank Books to order, Loose Leaf Devices of all kinds. Special Attention Given to All Mail Orders.

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The Adams Express Company in Philadelphia maintains a fleet of 146 Electric Trucks for city delivery, because they have proven to their own satisfaction that with the low rates and uniformly excellent service furnished by The Philadelphia Electric Company, electric delivery is the most economical and satisfactory system they can employ.

The Philadelphia Electric Company's rates for automobile battery charging compare favorably with similar rates in any large city in this country. Charging facilities are provided at convenient points.

Expert advice and assistance to users and prospective users of Electric Vehicles in Philadelphia is gladly furnished. Full and complete data is available covering upkeep cost, daily cost of running, comparative statistics and savings.

The Philadelphia Electric Company

Tel: { 3556 Greenpoint
3557 Greenpoint

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785 Humboldt Street

BROOKLYN, N. Y.

Manufacturers of

Bar Lead
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Spelter for Batteries in 1 lb. bars
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BEST QUALITY AT LOWEST PRICES

WE ALSO PURCHASE

Old Storage Battery Plates
Old Storage Battery Sediment
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Old Automobile Shoes and Inner Tubes
All kinds of Scrap Metals

Electric Commercial Vehicle

FOR

Innumerable Applications

EFFICIENCY

Irrisistible energy—instantly and continuously available—economically employed by the highest developed, most efficient and simplest engine known to science—the Electric Motor.

COSTS

Dreaded contingencies—the costly "incidents"—are reduced to a minimum; speculation gives way to the certainty of uniformly low operating costs. Facts and figures for the asking.

ASSURANCE

To get there and back—on railroad schedule (without expensive delays and compensating, injurious speeding); such is the regular performance characteristic of the Electric Vehicle.

CONTROL

The easy control of the Electric Vehicle is prompt and positive—therefore safe. To successfully operate the Electric Vehicle, one does not have to be an expert mechanician —therefore economy.

CHARGING

The remarkable simplicity of the Electric Vehicle eliminates the necessity of "tinkering"; while the charging of the powerful batteries is about as simple as "turning on" an electric lamp.

USE

Wherever the Electric Vehicle has been properly installed it has made good. Practically all the great "Commercial fleets" are Electric—the monetary investments running into the tens of millions.

The Electric Passenger Vehicle

for

Business and Pleasure

SPEED. More than you can use in the city—all that you'll ever require in the country—the Electric is as adaptable in its range of speed as any other type of car.

POWER. Real hill-climbing ability. The Electric Vehicle will travel 50, 75, 100 or more miles per charge, according to battery equipment.

CHARGING. Press a button—the rest is largely automatic. Simplicity itself and absolutely clean. Batteries can be charged with large amount of current in a short time or a small amount in a longer time (over night when not in use). For instance, if touring, batteries can be charged while you are at luncheon.

GARAGING. At home? Yes! And simple and clean. At public garages (look for Official Garage and Charging Station Signs of the Electric Vehicle Association), excellent and inexpensive service may readily be obtained.

ECONOMY. Mile for mile, all things considered, the Electric Vehicle is the cheapest car to run. Its low operating costs will be a pleasant surprise for you.

TIRES. The Electric Vehicle is easy on the roads—therefore easy on tires. Its tire costs are comparatively insignificant.

RELIABILITY. You will depend on the Electric Vehicle for it is worthy of your confidence—it will not fail you.

DISTINCTION. The character of the Electric Vehicle is an expression of good taste.

USAGE. The Electric Passenger Vehicle is primarily a business car as used by Doctors, Salesmen, Merchants, etc., but its ease of control; freedom from dirt and noise; smooth, easy riding qualities and reliability, have made it a great favorite with Milady for shopping, visiting and touring.

RESUME. The principles of Electric Vehicle design are founded on those developed in the electric railway; and their reliability and simplicity are on a par with the street, elevated and subway cars on which we so greatly depend.

Ask for interesting facts and figures. No obligation implied.

The Electric Vehicle Association of America

United Engineering Societies' Building

29 West 39th St., New York City

Electric Vehicle Association of America

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130 East 15th St.,
New York City

VICE-PRESIDENT
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YOU ARE INVITED TO HELP BOOST THE SALE AND USE OF THE ELECTRIC VEHICLE

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Tests can be made at the factories, at storehouses, under operating conditions, or at the laboratories of this Company as best suits your conditions. Our facilities are at your service.

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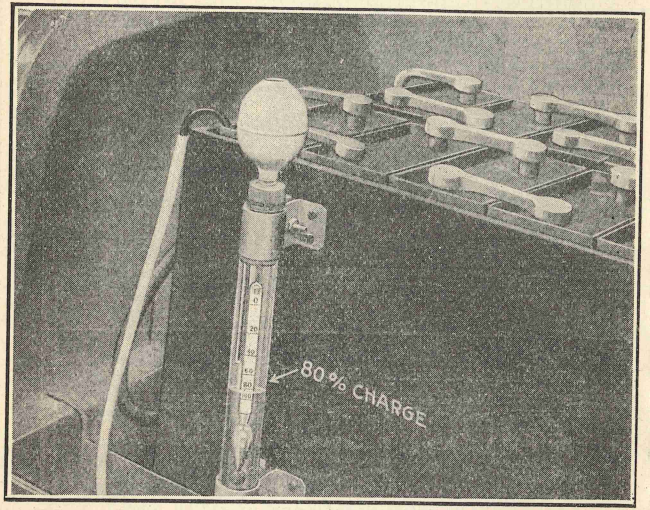
QUALITY 50 75 100 TESTED PRODUCT 100 PER CENT

EVERY VEHICLE USER SHOULD HAVE ONE

Instrument for Indicating Condition of Battery Charge

A so-called "milostat" for indicating the condition of charge of an electric battery at all times is shown in the accompanying illustration. This instrument is in principle a hydrometer, but instead of being graduated for specific-gravity readings, the divisions are made to represent percentages of the acid-density range from full charge to



HYDROMETER FOR SHOWING CHARGE OF BATTERY

full discharge. If, for instance, the battery is designed to operate the car for 100 miles on one charge, 100 per cent. represents a total distance of 100 miles.

Send for Circular.

FRITCHLE AUTOMOBILE & BATTERY CO.
DENVER, COLORADO

ELECTRIC VEHICLE CHARGING STATIONS.

In New York, Brooklyn and Suburbs.

The increase in the number of Electric Vehicles operating in Greater New York and its environs has been marked by the establishment of a considerable number of electric vehicle garages and charging stations. As indicated on pages 181-2, Chapter VI, the Central Station companies of the territories throughout the country have prepared lists of charging stations, and, in not a few instances, have Electric Vehicle Bureaus or representatives whose function is to collect and disseminate information with regard to the Electric Vehicle. The offices and locations of the Central Station companies operating in the Metropolitan District are given on the following pages, with a list of Electric Vehicle garages and charging stations, which has been very carefully checked and brought up to date. The effort has been made to include the necessary information as to location and the capacity of the charging facilities as well as the prices charged for the service. It is the experience of the several thousand owners and operators that in practically all instances the garages where such facilities are available are willing to extend the best which their service affords.

In order to graphically exhibit the locations of the charging stations not within the confines of Manhattan, the Bronx and Brooklyn, the accompanying map has been prepared and the signals

are placed so that the arrows point at the cities or towns where "boosts" may be obtained. Reference should be made to the detailed list for the exact location and facilities afforded as well as for the large number of stations in the City of New York which are not indicated, in order to avoid confusion. By an inspection of the map it will be seen that the Electric Vehicle of standard battery capacity may be operated efficiently and with high satisfaction because of the convenient location of these boosting stations.

The Electric Vehicle Association of America exercises a supervising interest in electric garages and charging stations. This supervision is indicated by the display of the official garage or charging station signs, as shown in figures 1 and 2, page 369. Garages display these blue and white enamelled signs prominently and the operator is thereby assured of competent attention.

A charging plug in two sizes has been standardized by the Electric Vehicle Association of America, as described on page 39 in order that confusion with regard to six or seven makes of plug may be avoided. If the standard plug is not used, it is strongly recommended that the owner carry a charging plug for his vehicle, so that if the necessary type is not at hand in the garage, temporary connections may be quickly made and delay in charging avoided.

Charging facilities of a nature similar to those described are available beyond the boundaries indicated and definite information will be forth-

coming from the Central Station representatives in the territories concerned.

Every operator, owner and prospective owner of an Electric Vehicle is invited to communicate by telephone or otherwise with the Secretary of the Electric Vehicle Association of America, 29 West 39th Street, New York City (Telephone 4600 Bryant), for any or all information concerning the Electric Vehicle. The Electric Vehicle representatives of the companies given below stand ready to offer information and assistance.

BROOKLYN, N. Y.

Edison Elec. Ill. Co. of Brooklyn, 360 Pearl Street.
Telephone, Main 8000

Flatbush Gas Company, 1034 Flatbush Avenue.
Telephone, Flatbush 1800

FAR ROCKAWAY, L. I.

Queens Borough Gas & El. Co., 347 Central Ave.
Telephone, Far Rockaway 1400

NEWARK, N. J.

Public Service Corp. of New Jersey, 759 Broad St.
Telephone, Market 7000

NEW YORK CITY.

The New York Edison Co., Irving Pl. & 15th St.
Telephone, Stuyvesant 5600

The United Elec. Lt. & Pr. Co., 130 E. 15th St.
Telephone, Stuyvesant 4980

QUEENS, L. I.

N. Y. & Queens E. L. & Pr. Co., 444 Jackson Ave.
Telephone, Astoria 1280

WESTCHESTER.

The Bronx Gas & El. Co., Walker & Frisby Aves.
Telephone, Westchester 500

Westchester Lighting Co., 1st Ave. & 1st St.
Telephone, Mt. Vernon 310

Yonkers Elec. Lt. & Pr. Co., 9 Manor House Sq.
Telephone, Yonkers 2630

ELECTRIC VEHICLE CHARGING STATIONS.

* Indicates emergency charging only. Stations not so indicated are prepared to supply regular charging and garaging.

NEW YORK CITY.

MANHATTAN.

Courtesy of The New York Electric Vehicle Association.

*The New York Edison Company..100 Water St.
60 amperes—120 volts—all hours—10c per kilowatt hour

*The New York Edison Company...546 Pearl St.
200 amperes—120 volts—all hours—10c per kilowatt hour

North Moore St. Garage...56-62 North Moore St.
150 amperes—120 volts—all hours—10c per kilowatt hour

*The New York Edison Co.....210 Lafayette St.
60 amperes—120 volts—all hours—10c per kilowatt hour

*The New York Edison Co.....152 Clinton St.
200 amperes—120 volts—all hours—10c per kilowatt hour

*The New York Edison Co.....98 Vandam St.
60 amperes—120 volts—all hours—10c per kilowatt hour

*Motor Delivery Company.....42 Downing St.
75 amperes—120 volts—all hours—$1.50 per boost

*Marseillaise French Baking Co.....48 Bank St.
50 amperes—120 volts—all hours—10c per kilowatt hour

*The New York Edison Co.....32 Horatio St.
60 amperes—120 volts—all hours—10c per kilowatt hour

*The New York Edison Co.....115 E. 12th St.
200 amperes—120 volts—all hours—10c per kilowatt hour

Piercy Contracting Company.....422 W. 15th St.
100 amperes—120 volts—all hours—10c per kilowatt hour

*The New York Edison Co.....27 W. 16th St.
60 amperes—120 volts—all hours—10c per kilowatt hour

Monahan Express Company.....216 W. 18th St.
50 amperes—120 volts—7:00 A.M. to 9:30 P.M.—7c per kilowatt hour

Exide Battery Depots, Inc., West Side Garage, 527-41 W. 23rd St.
100 amperes—120 volts—all hours—10c per kilowatt hour

*The United El. Lt. & Pr. Co.....520 W 24th St.
90 amperes—120 volts—all hours—10c per kilowatt hour

Exide Battery Depots, Inc., East Side Garage, 141 E. 25th St.
100 amperes—125 volts—all hours—10c per kilowatt hour

*The New York Edison Co.....147-9 E. 26th St.
60 amperes—120 volts—all hours—10c per kilowatt hour

*Storage Battery Supply Co.....239 E. 27th St.
45 amperes—120 volts—7:30 A.M. to 5:00 P.M. (except Sunday)

*The New York Edison Co.....452 W. 27th St.
60 amperes—120 volts—all hours—10c per kilowatt hour

Acme Electric Garage.....410 E. 32nd St.
100 amperes—120 volts—all hours—10c per kilowatt hour

Lexington Auto Garage.....150 E. 39th St.
75 amperes—120 volts—all hours—by the charge

*The New York Edison Co.....314 W. 41st St.
200 amperes—120 volts—all hours—10c per kilowatt hour

*The New York Edison Co....41st St. & 1st Ave.
200 amperes—120 volts—all hours—10c per kilowatt hour

W. L. Thompson.....651-5 W. 43rd St.
100 amperes—120 volts—all hours—$1.00 per boost

*U. S. Lighting & Heating Co.....16 W. 61st St.
50 amperes—120 volts—8 A.M. to 6 P. M. (except Sunday) by the kilowatt hour

F. W. Goodrich.....75 E. 52nd St.
50 amperes—120 volts—8 A.M. to 12 P.M.—by the boost

*The New York Edison Co.....118 W. 53rd St.
60 amperes—120 volts—all hours—10c per kilowatt hour

T. L. Proud Electric Co.....114 W. 54th St.
50 amperes—120 volts—all hours—$1.50 per boost

M. J. Buckley.....150 W. 56th St.
60 amperes—120 volts—all hours—$1.50 per boost

Baker Vehicle Company.....235 W. 56th St.
60 amperes—120 volts—all hours—by the ampere hour

*The New York Edison Co.....155 E. 60th St.
60 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

International Motor Co..W. End Ave. & 63rd St.
90 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

*The New York Edison Co.....170 W. 64th St.
60 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

Rauch & Lang Carriage Co.....57 W. 66th St.
50 *amperes*—120 *volts*—*all hours*—$1.00 *per boost*

*Edison Storage Battery Co....204-6 W. 76th St.
200 *amperes*—120 *volts*—8 *A.M. to* 6 *P.M. (except Sunday)* 6c *per kilowatt hour*

Dakota Stable Company.....200 W. 77th St.
75 *amperes*—120 *volts*—*all hours*—9c *per kilowatt hour*—*minimum charge* 75c

Detroit Electric Garage.....Broadway & 80th St.
50 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*—*minimum charge* 50c

Sterling Garage & Stable Co.....309 E. 80th St.
60 *amperes*—120 *volts*—*all hours*—*by the boost*

*The New York Edison Co.....123 E. 83rd St.
200 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

Yorkville Auto & Garage Co.....327 E. 84th St.
60 *amperes*—120 *volts*—*all hours*—50c *per boost*

*The New York Edison Co.....211 W. 84th St.
200 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

Niagara Livery & Motor Car Co....69 E. 89th St.
30 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

Turin Garage & Supply Company.53 W. 93rd St.
50 *amperes*—120 *volts*—*all hours*—*by the charge*

*The New York Edison Co.....171 W. 107th St.
60 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

*Harlem Electric Company.....6 E. 116th St.
50 *amperes*—120 *volts*—8 *A.M. to* 6 *P.M. (except Sunday) by the kilowatt hour*

*The New York Edison Co.....128 E. 121st St.
200 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

*The New York Edison Co.....259 W. 123rd St.
200 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

The United Elec. Lt. & Pr. Co...514 W. 147th St.
90 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

*The United Elec. Lt. & Pr. Co.
201st St., Harlem River
200 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour.*

*Audubon Storage Warehouse...1926 Amsterdam
100 *amperes*—100 *volts*—*all hours*—10c *per kilowatt hour*

BRONX.

*The N. Y. Edison Co.....Rider Ave. & 140th St.
100 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

*The New York Edison Co.....360 E. 149th St.
60 *amperes*—120 *volts*—10c *per kilowatt hour*

*The New York Edison Co.....Lafayette Ave.
200 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

*The New York Edison Co., Park Ave. & 189th St.
200 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

WESTCHESTER.

Bronx Gas & Electric Co.,
Zerega & Blackrock Aves., Unionport
Unlimited—125 *volts*—*all hours*—12c *per kilowatt hour*

*Bronx Gas & Electric Co.,
Walker & Frisby Aves., Westchester
60 *amperes*—125 *volts*—7 *A.M. to* 6 *P.M.*—12c *per kilowatt hour*

BROOKLYN.

Clinton Garage.....8 Clinton St.
70 *amperes*—125 *volts*—*all hours*—7c *per kilowatt hour*—*minimum charge* $1.00

*Edison Electric Ill. Co. of Brooklyn....95 Jay St.
180 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*

*Edison Electric Ill. Co. of Brooklyn.360 Pearl St.
60 *amperes*—125 *volts*—9 *A.M. to* 5:30 *P.M. (except Sunday)* 10c *per kilowatt hour*

*Edison El. Ill. Co. of B'klyn...26 Lexington Ave.
180 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*

*Edison El. Ill. Co. of B'klyn....1171 Myrtle Ave.
180 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour.*

*Edison El. Ill. Co. of B'klyn.....884 Broadway
60 *amperes*—125 *volts*—9 *A.M. to* 5:30 *P.M. (except Sunday)* 10c *per kilowatt hour*

*Edison El. Ill. Co. of B'klyn...1265 Atlantic Ave.
180 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*

*Edison El. Ill. Co. of B'klyn.....280 Carroll St.
180 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*
*Edison El. Ill. Co. of B'klyn.....366 Sumpter St.
180 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*
*Edison El. Ill. Co. of B'klyn.....Foot of 66th St.
40 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*
*Edison Electric Ill. Co. of Brooklyn,
Rodney & Ainslie Sts.
180 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*
McIntosh Brothers.....811 Union St.
60 *amperes*—110 *volts*—*all hours*—10c *per kilowatt hour*
Pastre's Auto Garage,
Ocean Parkway & Sherman St.
50 *amperes*—120 *volts*—*all hours*—*by the charge*
Brooklyn Electric Garage.....342 Flatbush Ave.
120 *amperes*—110 *volts*—*all hours*—6c *per kilowatt hour*
*Flatbush Gas Company.....273 Clarkson St.
200 *amperes*—110 *volts*—*all hours*—5c *per kilowatt hour*

CONEY ISLAND, NEW YORK, 16 MILES.

*Edison Electric Ill. Co. of Brooklyn,
W. 12th Street & R. R. Ave.
180 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*
*Edison Electric Ill. Co. of Brooklyn,
Surf Ave., near W. 14th St.
60 *amperes*—125 *volts*—9 *A.M. to* 5:30 *P.M.* (*except Sunday*)
10c *per kilowatt hour*

CHARGING STATIONS OUTSIDE OF NEW YORK CITY (SEE MAP).

Distance Reckoned from Columbus Circle.

ASBURY PARK, N. J.—53 MILES.
Zacharias Garage, Sewall Ave. & Main St.
85 *amperes*—125 *volts*—*all hours*—$1.50 *per boost*

BRIDGEPORT, CONN.—56 MILES.
General Motors Service & Truck Co., 554 Fairfield Ave.
200 *amperes*—110-220 *volts*—*all hours*—7c *per kilowatt hour*

CRANFORD, N. J.—24 MILES.
*Greenhut Siegel-Cooper Co., 13 Union Ave.
40 *amperes*—110 *volts*—7 *A.M. to* 6 *P.M.*

DEAL, N. J.—50 MILES.
*Fairfield Dairy Company.

EAST ORANGE, N. J.—15 MILES.
Electric Vehicle Garage, 161 McKinley Ave.
75 *amperes*—120 *volts*—*all hours*—*per boost*—$1.50-$2.00

EDGEMERE, LONG ISLAND—24 MILES.
Schildkraut's Garage.
30 *amperes*—110 *volts*—*all hours*

ELIZABETH, N. J.—15 MILES.
Elizabeth Automobile Co., 14-16 Westfield Ave.
50 *amperes*—110 *volts*—*all hours*—10c *per kilowatt hour*

FLUSHING, LONG ISLAND—6 MILES.
New York & Queens Electric Light & Power Co., 46 Lawrence St.
160 *amperes*—125 *volts*—*all hours*—50c *plus* 6c *per k.w. hour*

GARDEN CITY, LONG ISLAND—19 MILES.
Garden City Garage, 7th St. & Franklin Ave.
30 *amperes*—50 *volts*—*all hours*—$1.50 *per boost*

GLEN COVE, LONG ISLAND—23 MILES.
*Glencove Light & Power Co.
30 *amperes*—110 *volts*—*all hours*—*by the boost*

GREENWICH, CONN.—28 MILES.
Minchin's Garage, Mason St.
40 *amperes*—125 *volts*—*all hours*—7½c *per kilowatt hour*

HOBOKEN, N. J.—3 MILES.
*Public Service Electric Co., 14th & Bloomfield Sts.
Unlimited—120 *volts*—*all hours*—10c *per kilowatt hour*

JAMAICA, LONG ISLAND—9 MILES.
New York & Queens Electric Light & Power Co., Van Wyck & Atlantic Aves.
100 *amperes*—125 *volts*—*all hours*—50c *plus* 6c *per k.w. hour*

JERSEY CITY, N. J.—4 MILES.

*A. B. C. Electric Elevator Co., Pacific Ave. & Forest St.

60 *amperes*—110 *volts*—7:30 *A.M. to* 5 *P.M. (except Sunday)* $1.00 *per boost*

E. B. Ryder, 2563 Boulevard.

40 *amperes*—120 *volts*—*all hours*—6c *per kilowatt hour*

LONG BRANCH, N. J.—45 MILES.

Andrews Garage, South Broadway.

25 *amperes*—120 *volts*—7:30 *A.M. to* 9 *P.M.*

LONG ISLAND CITY, N. Y.—2 MILES.

New York & Queens Electric Lt. & Pr. Co., Hamilton St. & Harris Ave.

50 *amperes*—125 *volts*—*all hours*—50c *plus* 6c *per k.w. hour*

New York & Queens Electric Lt. & Pr. Co., 444 Jackson Ave.

50 *amperes*—125 *volts*—*all hours*—50c *plus* 6c *per k.w. hour*

MASPETH, LONG ISLAND—3 MILES.

New York & Queens Electric Lt. & Pr. Co., 2227 Flushing Ave.

80 *amperes*—125 *volts*—*all hours*—50c *plus* 6c *per k.w hour*

MILLBURN, N. J.—21 MILES.

*H. I. Bawden, Hillside Ave.

20 *amperes*—110 *volts*—*Private Garage*

MONTCLAIR, N. J.—17 MILES.

*Fairfield Dairy Co., 139 Glenridge Ave.

100 *amperes*—120 *volts*

MT. VERNON, N. Y.—14 MILES.

*Westchester Lighting Co., 1st & Union Aves.

60 *amperes*—125 *volts*—*all hours*—10c *per kilowatt hour*—*minimum charge* $1.00

Mt. Vernon Charging Station, 51 N. 3d Ave.

50 *amperes*—135 *volts*—7 *A.M. to* 7 *P.M. (except Sunday) minimum charge* $1.00

NEWARK, N. J.—11 MILES.

The Electric Garage Co., 123 Washington St.

180 *amperes*—120 *volts*—*all hours*—6c *per kilowatt hour, minimum charge* 50c

NEW HAVEN, CONN.—75 MILES.

Holcomb Co., 105 Goffe St.

400 *amperes*—120 *volts*—*all hours*—6c *per kilowatt hour*

Reichert Auto Co., 44 Temple St.

30 *amperes*—110 *volts*—*all hours*

Kirk's Garage, 213 Crown St.

100 *amperes*—115 *volts*—*all hours*—6c *per kilowatt hour*—*minimum charge* $1.00

NEW ROCHELLE, N. Y.—18 MILES.

C. B. Poellmitz & Son, 351 Huguenot St.

60 *amperes*—125 *volts*—7 *A.M. to* 10 *P.M.*—10c *per kilowatt hour*

PASSAIC, N. J.—11 MILES.

*Public Service Electric Co., 40 Columbia Ave.

Unlimited—120 *volts*—*all hours*—10c *per kilowatt hour*

PATERSON, N. J.—19 MILES.

*Public Service Electric Co., Prospect & Van Houton.

150 *amperes*—120 *volts*—*all hours*—10c *per kilowatt hour*

E. E. Mayer, 153 Oliver St.

PEEKSKILL, N. Y.—41 MILES.

Ash's Garage, Washington St.

*Peekskill Railway & Light Co.

75 *amperes*—100 *volts*—*all hours*—*by the kilowatt hour*

PLAINFIELD, N. J.—26 MILES.

F. L. C. Martin Auto Co., 310 Park Ave.

Laing Machine Auto Repair Co., 410 Sycamore St.

30 *amperes*—*all hours*—10 *per kilowatt hour*

*Spicer Mfg. Co., 4th St. between Madison & Central Aves.

150 *amperes*—240 *volts*—*all hours (except bet. Saturday noon and Monday morning)* 1c *per ampere hour*

Service Motor Car Co., 333 Park Ave.

50 *amperes*

PORTCHESTER, N. Y.—26 MILES.

City Garage, Factory Pl. 50 *amperes*—125 *volts*

PORTCHESTER (Continued).

Ernest Simmons Mfg. Co., Westchester Ave.

60 *amperes*—120 *volts*—7:30 *A.M. to* 5 *P.M. (Saturday to* 12 *noon) by the kilowatt hour*

PORT JEFFERSON, LONG ISL.—55 MILES.

F. C. Griswold & Co., Main St.

100 *amperes*—125 *volts—all hours*

Bishop & Loper.

40 *amperes*—125 *volts—all hours—by the kilowatt hour*

ROSLYN, LONG ISLAND—20 MILES.

*Nassau Light & Power Co., Pryor's Rd. between Roslyn & Willis Aves.

60 *amperes*—80 *volts—all hours—by the kilowatt hour*

RUTHERFORD, N. J.—9 MILES.

Favier Bros., 20 Union Ave.

50 *amperes*

RYE, N. Y.—25 MILES.

Edwards & Halstead, Post Rd.

50 *amperes*—110 *volts—all hours—*15*c per kilowatt hour*

SEA BRIGHT, N. J.—42 MILES.

Zobel's Garage, Ocean Ave.

40 *amperes*—120 *volts—all hours—by the charge*

SOUTH NORWALK, CONN.—42 MILES.

*City of Norwalk Electric Works, State St.

1000 *amperes*—270 *volts—all hours—by the kilowatt hour*

George N. McKibbin, 47 Elmwood Ave.

30 *amperes—all hours (except Sunday)* 8*c per kilowatt hour —minimum charge* $1.00

STAMFORD, CONN.—35 MILES.

Stamford Gas & Electric Co., Atlantic & South Sts.

500 *amperes*—175 *volts*—1*c per ampere hour—minimum charge* $1.00

SUMMIT, N. J.—25 MILES.

Commonwealth Water & Lt. Co., Beechwood Rd. & Bank St.

75 *amperes*—120 *volts—all hours*

TRENTON, N. J.—62 MILES.

J. L. Brock's Garage, 332 E. State St.

50 *amperes*—220 *volts—all hours—by the kilowatt hour*

UNION HILL, N. J.—5 MILES.

Union Auto Co., 130 Columbia St.

30 *amperes*—125 *volts—all hours*

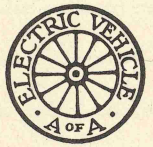
YONKERS, N. Y.—13 MILES.

*The Yonkers Elec. Lt. & Pr. Co., 2-10 Columbus Ave.

50 *amperes*—120 *volts—all hours—*13*c per kilowatt hour*

*The Yonkers Elec. Lt. & Pr. Co., 9 Manor House Sq.

50 *amperes*—120 *volts*—9 *A.M. to* 5:30 *P.M. (except Sunday)* 13*c per kilowatt hour*



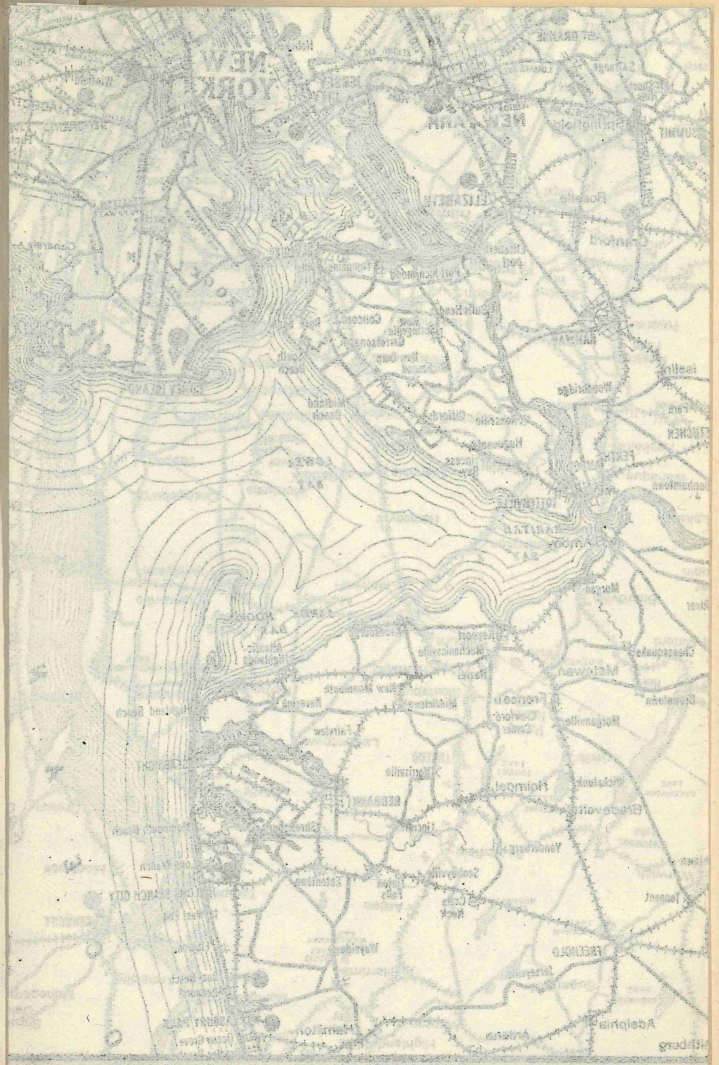
MEMBERS BUTTON
ELECTRIC VEHICLE ASSOCIATION OF AMERICA

Fig. 1.

Fig. 2.

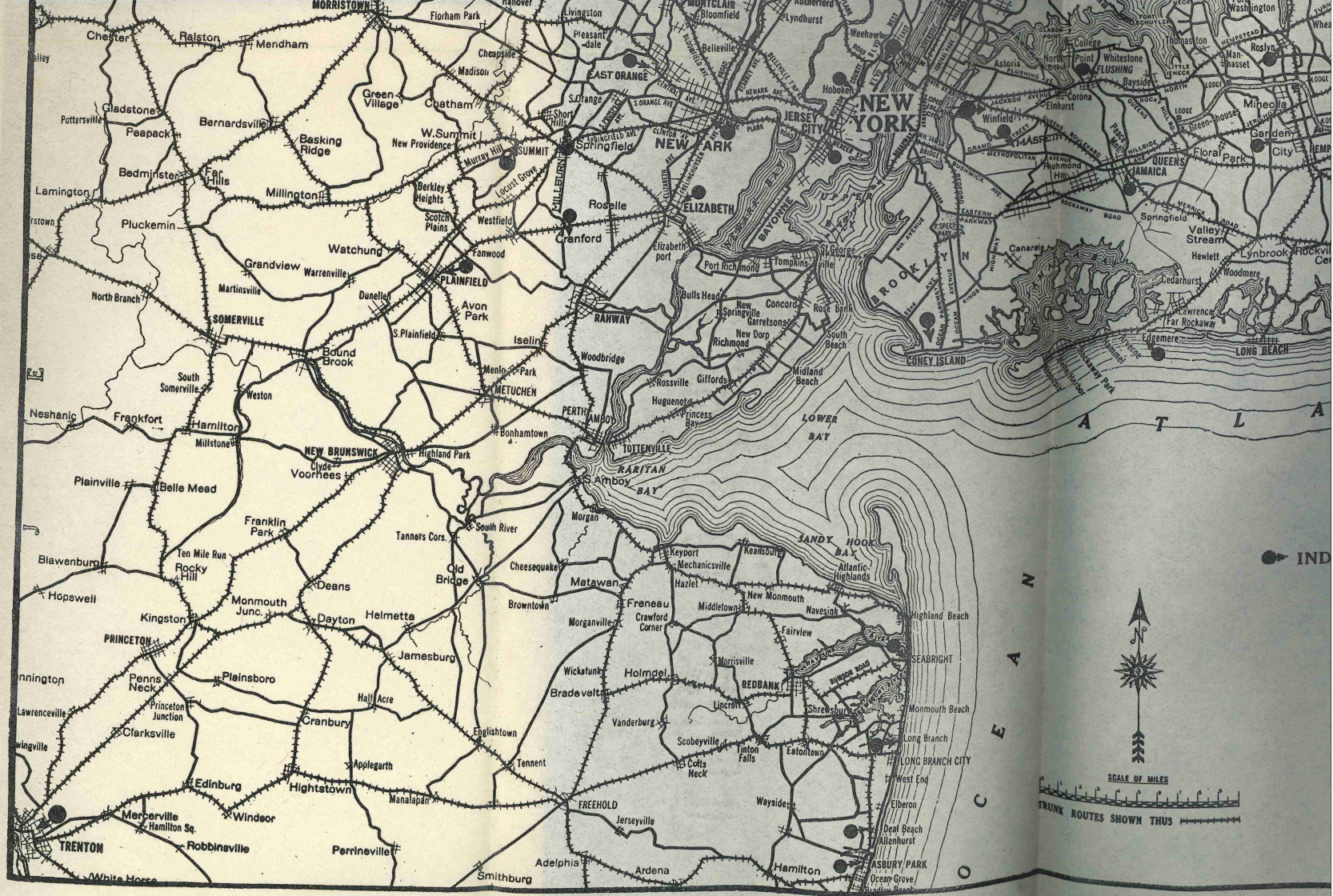
OFFICIAL GARAGE AND CHARGING STATION SIGNS ISSUED BY THE ELECTRIC VEHICLE ASSOCIATION OF AMERICA

MEMORANDA



Greenville
Westtown
Florida
Highland Mills
Monroe
Fort Montgomery
Annsville
Brick House
Unionville
Pine Island
Sugar Loaf
Harriman
Haines ville
Colesville
Amity
Edenville
Arden
PEEKSKILL
Tompkins Cove
Warwick
Montrose
New Milford
Greenwood Lake
Southfield
Sussex
Vernon
Thiells
Croton
Tuttles Corners
Lakeville
TUXEDO
Ladentown
Haverstraw
Mt Pisgah
Hamburg
Moe
Sterling Furnace
Sloatsburg
Hempstead
Congers
OSSINING
Branchville
Augusta
Ross Corner
Hewitt
Ringwood Manor
Ramapo
New City
Uttertown
Franklin Furnace
W Milford
Hillburn
SUFFERN
Spring Valley
Lafayette
Boardville
Monsey
Clarksville
Ogdensburg
Stockholm
Upper Macopin
Mahwah
Nanuet
W Nyack
NYACK
Woodruff Gap
Postville
Darlington
Pearl River
Newton
Hopewell
Oak Ridge
Echo Lake
Midvale
Ramsey
Orangeburg
Sparta
Newfoundland
Charlotteburg
Wanaque
Oakland
Allendale
Saddle River
Montvale
Tappan
Petersburg
Haskell
Waldwick
Woodcliff
Andover
Woodport
Bloomingdale
Pompton
Wyckoff
Hohokus
Hillsdale
Rivervale
Westwood
Hurd
Marcella
Pompton Plains
Ridgewood
Emerson
Harrington Park
Demarest
Tranquility
Hibernia
Pequannock
Hawthorne
New Milford
Alpine
Cresskill
Berkshire Valley
Rockaway Valley
Mountain View
Haledon
Brooklyn
Mount Arlington
Beach Glen
Powerville
Towaco
Lincoln Park
PATERSON
Arcola
N Hackensack
Bergenfield
Tenafly
Stanhope
Netcong
Wharton
Rockaway
Dover
BOONTON
South Paterson
ENGLEWOOD
Ledgewood
Denville
Clinton
Singac
HACKENSACK
Leonia
Linwood
Kenvil
Succasunna
Tabor
Persippany
Little Falls
Lodi
Flanders
Caldwell
Upper Montclair
PASSAIC
Little Ferry
Fort Lee
Bartley
Mount Freedom
Morris Plains
Whippany
Verona
Ridgefield
Rutherford
MORRISTOWN
Hanover
Florham Park
Livingston
MONTCLAIR
Bloomfield
Lyndhurst
Weehawken
Chester
Ralston
Mendham
Pleasant dale
Belleville
Cheapside
Madison
EAST ORANGE
Hoboken
Astoria
Green Village
Chatham
S Orange
Short Hills
JERSEY CITY
NEW YORK
Winfield
Elmhurst
Gladstone

NEW YORK
JERSEY CITY
HOBOKEN
HACKENSACK
PASSAIC
ENGLEWOOD
Fort Montgomery
Annsville
PEEKSKILL
Montrose
Tompkins Cove
Haverstraw
Thiells
Congers
New City
Hempstead
Spring Valley
Clarksville
Nanuet
W.Nyack
Monsey
Pearl River
Orangeburg
Montvale
Saddle River
Tappan
Woodcliff
Hillsdale
Rivervale
Westwood
Emerson
Harrington Park
Closter
New Milford
Alpine
Cresskill
Tenafly
Englewood Cliffs
Leonia
Cinnaminson
Fort Lee
Little Ferry
Ridgefield
Rutherford
Lyndhurst
Weehawken
Secaucus
Oregon
Shenks Oak
Monegan
Baldwin Place
Osceola
W.Somers
Somers
Somers Center
Yorktown
Amawalk
Yorktown Heights
Katonah
Cross River
Croton Falls
Croton
Bedford Hills
Pine Bridge
Kitchawan
Mt.Kisco
Newcastle
Cors
Millwood
Chappaqua
Pleasantville
Briarcliff
Scarborough
Hawthorne
Eastview
Tarrytown
Elmsford
Irvington
White Plains
Purchase
Ardsley
Hartsdale
Dobbs Ferry
Hastings
Yonkers
Tuckahoe
Scarsdale
Bronxville
Mamaroneck
Larchmont
Mount Vernon
New Rochelle
Pelham
Pelham Manor
Hunter Island
City Island
Port Washington
Manhasset
Roslyn
Whitestone
Flushing
Bayside
Little Neck
Douglaston
College Point
North Beach
Astoria
Corona
Elmhurst
Jackson Heights
Winfield
Maspeth
Ridgewood
Glendale
Woodhaven
Richmond Hill
Kew Gardens
Forest Hills
Rego Park
Jamaica
Queens Village
Hollis
Floral Park
Bellerose
Garden City
Mineola
Greenhouses
Westbury
Old Westbury
Jericho
Wheatley
Greenvale
Syosset
Cold Spring
Woodbury
Plainview
Melville
Hicksville
Central Park
Farmingdale
Bethpage
Lattingtown
Locust Valley
Oyster Bay
Glen Cove
Sea Cliff
Glenwood Landing
Roslyn Harbor
Norwich
Bayville
Mill Neck
Centerport
Huntington
Harbor
Fairground
Northport
Middleville
Kings Park
Lloyd Neck
Eaton Neck
Milton Pt.
Rocky Pt.
Plum Pt.
Yellow House
Setauket
E.Setauket
Port Jefferson
Miller Place
Stony Brook
St.James
Smithtown
Commack
Smithtown Branch
Middle Island
Coram
New Village
Lake Ronkonkoma
Ronkonkoma
Central Islip
Brentwood
Deer Park
Bohemia
Patchogue
Brookhaven
Blue Point
Bayport
Sayville
Oakdale
E.Islip
Islip
Bayshore
Greenwich
Mianus
Glenville
Stamford
Glenbrook
Noroton
Darien
Noroton Pt.
Collenden Pt.
Shippan Point
Sound Beach
South Norwalk
E.Norwalk
Saugatuck
Compo Beach
Greens Farms
Southport
Westport
New Canaan
N.Stamford
Banksville
Long Ridge
Stanwich
Lockwood
Armonk
Byram Lake
Kensico Reservoir
Bedford
Scott Corners
Vista
Wilton
S.Wilton
Cannon
Aspetuck
Lewisboro
Trinity Lake
Cross Pond
Cross River Reservoir
Titicus
S.Salem
Ridgefield
Branchville
Georgetown
Redding Ridge
Redding
Easton
Stepney
Upper Stepney
Hattertown
Monroe
Huntington
Nichols
Shelton
Derby
Ansonia
New Haven
Westville
Allingtown
W.Haven
Savin Rock
Milford
Stratford
Bridgeport
Fairfield
N.Salem
Goldens Bridge
Purdy
Salem Center
Croton Lake
Croton Reservoir
Amawalk Reservoir
Titicus Reservoir
Cross River Reservoir
Byram Lake
Kensico Reservoir
Long Island Sound
Hutchinson River Parkway
Merritt Parkway
Wilbur Cross Parkway
Long Island Motor Parkway
Lodge
Turnpike


MORRISTOWN
Florham Park
Hanover
Livingston
MONTCLAIR
Bloomfield
Lyndhurst
Weehawken
Chester
Ralston
Mendham
Pleasant-dale
Cheapside
Madison
EAST ORANGE
Belleville
Hoboken
NEW YORK
Astoria
College Point
Whitestone
FLUSHING
Bayside
Thomaston
Roslyn
Man-hasset
Washington
Green Village
Chatham
S. Orange
Short Hills
JERSEY CITY
Corona
Elmhurst
Winfield
Mineola
Gladstone
Pottersville
Peapack
Bernardsville
Basking Ridge
W. Summit
New Providence
SUMMIT
Springfield
NEWARK
Garden City
Floral Park
Bedminster
Far Hills
Murray Hill
Locust Grove
Millington
Berkley Heights
Scotch Plains
Westfield
Roselle
ELIZABETH
MASPETH
Richmond Hill
QUEENS
JAMAICA
Lamington
Pluckemin
Watchung
Cranford
Elizabeth-port
Springfield
Valley Stream
Lynbrook
Hewlett
Woodmere
Grandview
Warrenville
Fanwood
PLAINFIELD
Port Richmond
Tompkinsville
St. George
Canarsie
North Branch
Martinsville
Dunellen
Avon Park
Bulls Head
New Springville
Concord
Rose bank
Cedarhurst
Lawrence
Far Rockaway
SOMERVILLE
S. Plainfield
RAHWAY
Garretsons
New Dorp
Richmond
South Beach
Edgemere
LONG BEACH
Bound Brook
Iselin
Woodbridge
CONEY ISLAND
South Somerville
Menlo Park
METUCHEN
Rossville
Giffords
Midland Beach
Weston
Huguenot
Princess Bay
Neshanic
Frankfort
Hamilton
Millstone
PERTH AMBOY
Bonhamtown
TOTTENVILLE
LOWER BAY
NEW BRUNSWICK
Highland Park
Clyde
Voorhees
RARITAN BAY
S. Amboy
Plainville
Belle Mead
Franklin Park
Morgan
South River
Tanners Cors.
SANDY HOOK BAY
Keyport
Mechanicsville
Keansburg
Atlantic Highlands
Blawenburg
Ten Mile Run
Rocky Hill
Old Bridge
Cheesequake
Matawan
Hazlet
Hopewell
Deans
Monmouth Junc.
Browntown
Freneau
New Monmouth
Middletown
Navesink
Highland Beach
Kingston
Dayton
Helmetta
Morganville
Crawford Corner
Fairview
PRINCETON
Jamesburg
Morrisville
SEABRIGHT
Penns Neck
Plainsboro
Wickatunk
Holmdel
REDBANK
Bradevelt
Lincroft
Shrewsbury
Monmouth Beach
Lawrenceville
Princeton Junction
Half Acre
Cranbury
Vanderburg
Long Branch
Clarksville
Englishtown
Scobeyville
Tinton Falls
Eatontown
LONG BRANCH CITY
Applegarth
Tennent
Cofts Neck
West End
Edinburg
Hightstown
Manalapan
FREEHOLD
Waysides
Elberon
Mercerville
Hamilton Sq.
Windsor
Jerseyville
Deal Beach
Allenhurst
TRENTON
Robbinsville
Perrineville
Adelphia
Ardena
Hamilton
ASBURY PARK
Ocean Grove
Smithburg
White Horse
OCEAN
ATLA
IND
SCALE OF MILES
TRUNK ROUTES SHOWN THUS

INDICATES ELECTRIC VEHICLE CHARGING STATIONS.

ELECTRIC VEHICLE ROUTES AND CHARGING STATIONS SUBURBS OF NEW YORK CITY

FOR NEW YORK CITY AND BROOKLYN
SEE LISTS ON PAGES 357-372
"THE ELECTRIC VEHICLE HAND-BOOK"

SCALE OF MILES

TRUNK ROUTES SHOWN THUS

Courtesy of The Automobile Club of America.